IRON AND STEEL ENGINEER

J. F. KELLY, Editor

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EDITORIALS

ANNUAL CONVENTION AND IRON AND STEEL EXPOSITION

There is, perhaps, no more striking testimony to the popularity of the Annual Convention and Iron and Steel Exposition than the increased attendance each year at these two events.

This very popularity lays an additional responsibility upon the shoulders of this Society, and makes the task of those men who have accepted the responsibility of governing and managing this Convention no mean or slight undertaking.

To further enhance the value of the Convention and Exposition, a technical program has been prepared which will surpass anything that has been attempted at Conventions so far. With respect to the Exposition, many new features have been introduced this year. So much so, that the time-honored structure of the past will have become enlarged to a degree that we may lay claim to almost a new work.

Our first Convention was attended by 28 persons; last year 25,000 persons witnessed the handiwork of the A.I.&S.E.E., and still we stand on the threshold of unlimited opportunities.

The question is sometimes asked what are the benefits to be derived from attendance at Conventions? Let us lay aside, for the moment, the value of the technical sessions at the Convention, and analyze the results that are obtained through personal contact. Did you ever stop to realize the size of the A.I.&S.E.E. Family? Where practically every person who attends has a speaking acquaintanceship with one another. This did not come about in a day, month or year, but through the faithful attendance of the membership each year. What does this acquaintanceship bring to the Steel Industry as a whole? It has helped practically to standardize Electrification in the Steel Industry. Acquaintanceship has made it possible for the Engineers to personally canvass each other when confronted with electrical, mechanical and combustion problems, the design, building, installation, operation and maintenance of apparatus which is under their supervision.

Many of these advantages which have been enumerated may also be secured at the periodical section meetings, however, you have the added advantage in conventions of securing the opinions of practically all of the Steel Mill Engineers in the Iron and Steel Industry throughout the United States.

The technical program for this year is as follows:

Monday—Electrical Safety Day.

Tuesday—High Tension Switching.

Wednesday—Frog Leg Windings.

Thursday—Electric Heating Committee's report. The possibilities of Electric Heating will be traced from the ingot to the finished bar. Electric Melting, and the economies of Electric Heating will also be discussed.

Friday—Auxiliaries and auxiliary drives for steam electric generating station.

A new feature at our technical sessions will be a series of moving pictures, covering the operation of apparatus of special interest to the Iron and Steel Engineer.

For the convenience of the manufacturers and the information of all others interested parties, there is inserted in this issue a folder showing the Exposition layout, Rules and Regulations for exhibitors, as well as other items of interest for those who are in any way connected with the Iron and Steel Industry.

FUEL SAVINGS CONFERENCE

More than 500 engineers connected with the Iron and Steel Industry were in attendance at the annual Fuel Savings Conference held under the auspices of the Combustion Engineering Section of the Association of Iron and Steel Electrical Engineers at the Wm. Penn Hotel, Pittsburgh, on Wednesday and Thursday, May 13th and 14th, 1925.

All the big steel mill centers throughout the United States were represented at the conference.

In addition to the morning and afternoon technical sessions, the entire ball room of the hotel was devoted to an exhibit of the latest developments of apparatus used by the Combustion Engineering Division.

The program follows:

WEDNESDAY, MAY 13th

COMBUSTION IN STEEL MILL FURNACES

—By—

C. H. Smoot, President Smoot Engineering Co., New York, N. Y.

Thomas Peebles, The Hagan Corp., Pittsburgh, Pa.

C. S. Carrick, President and General Manager, Carrick Engineering Co., Chicago, Ill.

B. G. Bailey, President Bailey Meter Co., Cleveland, Ohio.

H. K. Huessener, President American Heat Economy Bureau, Pittsburgh, Pa.

DISCUSSION OF THE PAPERS PRESENTED IN THE FORENOON

By Engineers of the Iron and Steel Industry

INSULATION OF HOT SURFACES AND FURNACE WALLS

By L. B. McMillan, Consulting Engineer, Johns Manville, Inc., New York, N. Y.

Reception and Dinner—Combustion Engineering Division and Guests

THURSDAY, MAY 14th

GENERATION OF STEAM FROM COKE BRAIZE

By John VanBrunt, Vice President in Charge Engineering, Combustion Engineering Co., New York, N. Y.

COKE BRAIZE

By G. C. Emmons, Steam and Efficiency Engineer, Republic Iron and Steel Co., Youngstown, Ohio.

A NEW USE FOR BLAST FURNACE GAS

By G. R. McDermott, Assistant Chief Engineer, Illinois Steel Company, South Chicago, Ill.

All papers, together with the discussion will appear in the July issue of the Iron and Steel Engineer.

The next annual Fuel Savings Conference will be held at Birmingham, Ala., in the month of March, in connection with the midwinter convention of the A.I.&S.E.E.

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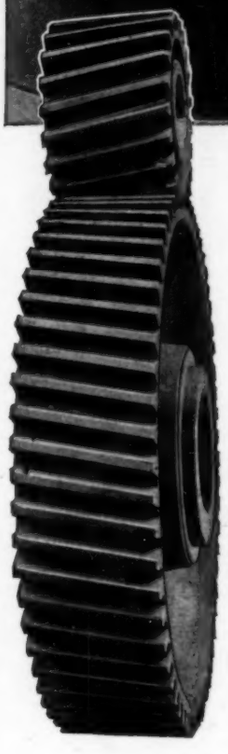
Nuttall Makes Silent Crane Gears



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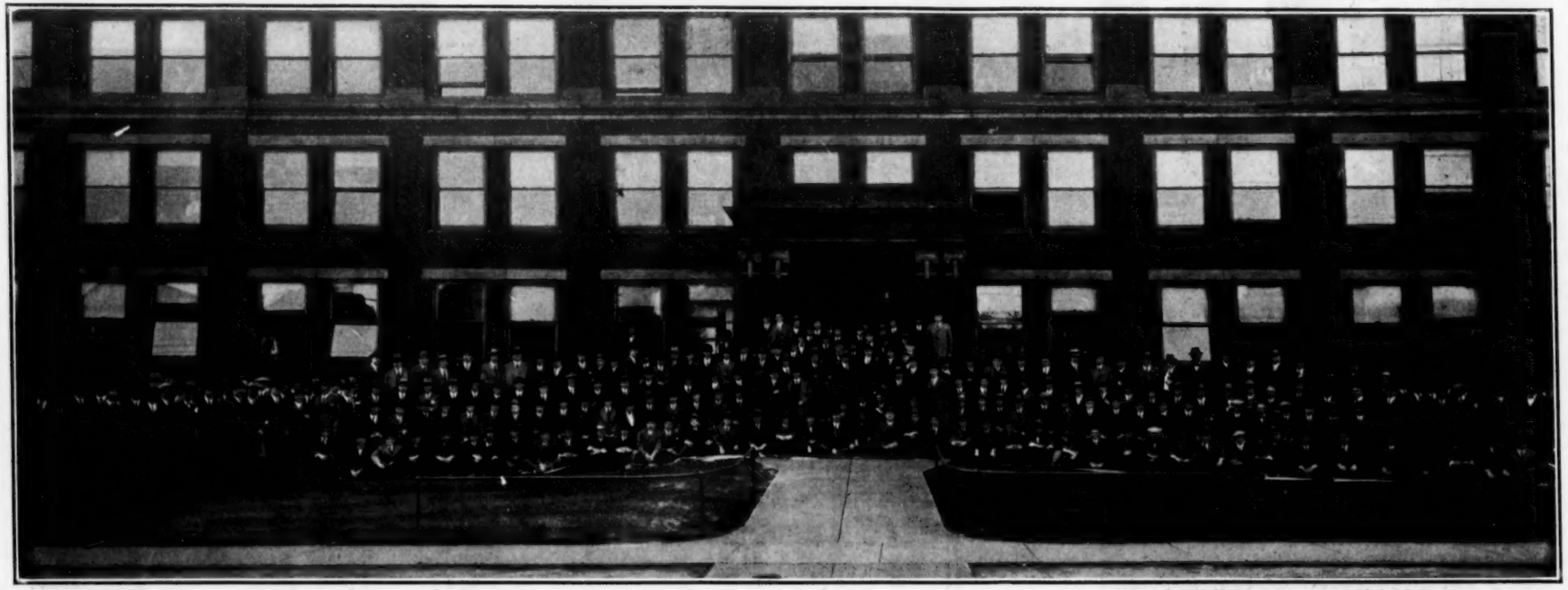
ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINNERS INSPECTION TRIP YOUNGSTOWN SHEET & TUBE COMPANY MODERN SHEET MILL PLANT APRIL 8, 1925.



Over 400 Sheet Mill operators and engineers attended the inspection trip of the A. I. & S. E. E. to the Modern Sheet Mill Plant of the Youngstown Sheet & Tube Company, Wednesday, April 8th, 1925.

A special train conveyed the visitors to the plant where the executives of the Youngstown Sheet & Tube Company met the visitors and extended a royal welcome.

Guides were provided to point out all the new features and developments in the art of sheet making.

In the evening the visitors were entertained with a banquet at the Ohio Hotel as the guests of the Youngstown Sheet & Tube Company.

R. B. Gerhardt, Assistant General Manager, Bethlehem Steel Company, Sparrows Point, Md., acted as toastmaster.

Mr. E. L. McElhaney, associated with Leif Lee, Consulting Engineer, Youngstown, Ohio, described the mechanical equipment of the sheet mill. Mr. Strickland Kneass, Combustion Engineer, of the Youngstown Sheet & Tube Company, spoke at some length on the combustion problems of the new sheet mill. Mr. E. F. Rhoades described the electrical equipment of the new sheet mill. The papers presented by these men appear on pages 222 to 225 of this issue.

This trip was voted one of the most successful in the history of the Association.

Mr. J. M. Ferris, Superintendent of Electrical and Mechanical Departments of the Youngstown Sheet & Tube Company, was master of ceremonies.

*Factors Involved in the Selection of Direct-Connected and Geared Main Roll Drives**

By E. A. HURME†

THE subject of Direct-Connected and Geared Main Roll Drives is not new, as the files of several engineering journals contain a number of articles dealing with different phases of this subject. It is the object of this paper to set forth collectively the main fundamental factors which should be given consideration in studying the subject of steel mill main roll drives and to state briefly the significance of each of these factors.

The following is a brief summary of the subjects which will be covered:

1. Object of the paper.
2. Development of Main Roll Drives.
   Industry has gradually changed from the early direct-connected motors to the present day more extensive use of geared units. At present only 30 per cent of the new installations are direct-connected, while 69 per cent are geared.
3. Frequency.
   Twenty years ago 25 cycle power predominated in the steel mill industry. There were good reasons for that. Today 23 per cent of all new installations are 25 cycle and fully 75 per cent are 60 cycle.
4. Power Factor.
   On early installations little, if any, attention was given to the power factor. Today, it is attracting considerable attention. Causes of low power factor are described and the interrelation of speed and power factor illustrated.
5. Methods of Connecting Main Roll Drives.
   Description with advantages and limitations of each method:
   a. Direct drive.
   b. Chain drive.
   c. Rope drive.
   d. Gear drive.
6. Brief history and development of Gear Drives.
   a. Lubrication.
      Requirements for proper lubrication, especially in connection with gear units.
7. Importance of Accurate Alignment.
8. Couplings.
   Necessity for good flexible connecting link.
9. Application of Fly-wheels.
   Uses for and benefits derived from properly applied fly-wheels.
10. Position of Fly-wheel.
    Advantages and limitations of each of the following locations:
    a. In the rotor of the motor.
    b. On the motor shaft.
    c. On its own shaft and bearings operating at mill speed.
    d. On its own shaft and bearings operating at motor speed.
    e. On the gear pinion shaft.
11. Control.
    Proper utilization of fly-wheel effect requires adequate control. Different methods of control are described with advantages and disadvantages of each.
12. Cost of Installation and the Different factors Involved.
13. Maintenance.
14. Standardization.
15. Plate Mill Drives.
16. Structural Mill Drives.
17. Sheet Mill Drives.
18. Merchant Mill Drives.

The last part of the paper goes more in detail concerning the initial cost, performance and space requirements of the four preceding mill drives. Recommended horsepower ratings and speeds are given, together with average fly-wheel effect requirements for each size and type of mill.

The information given herein has been obtained through the close co-operation of many of the electrical, mill machinery, gear and coupling manufacturers. Also many operating men have generously assisted with application and test data.

The information thus obtained has been carefully analyzed, and the results of the analysis submitted to the various manufacturers for their comments and suggestions. It will, therefore, be appreciated that the information given in this paper represents the accumulated experience and best judgment of a large number of engineers and manufacturers directly interested in this subject.

The question of the advantage or disadvantage of one method of drive, as compared with the other, is a broad one. The several factors involved, such as first cost, performance, space occupied, fly-wheel effect, maintenance, etc., vary in their relative importance in different plants, and at times an extensive analysis is required before the final choice is made.

It may be of interest to mention that, for the first time, price and performance curves of various methods of drives for several representative types of mills will be published. This comparative data is so compiled as to make a ready reference which will enable steel mill executives and electrical engineers to more thoroughly analyze their problems and will assist in the selection of the type of drive best suited for the conditions.

REVIEW OF DEVELOPMENT OF MAIN ROLL DRIVES

Twenty years ago when electric motors first were applied to main roll drives, steam engines were almost universally used, either direct-connected or through belt or rope drives, and in some cases through spur gear reduction units. Some sheet and Belgian mills still are driven by multiple rope drives, and some small merchant mills use belt or chain drives.

*To be presented before Pittsburgh Section, March 21, 1925.

†Manager, Steel Mill Section, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

A number of the early steam engine installations are still in service. They are mostly of the slow-speed type using direct-connected engines.

When electric motors first were installed for driving rolling mills, most of them also were direct-connected and to this extent followed existing steam engine practice. This required rather expensive motor units. At that time, the state of development of the reduction gear was such that it was not considered satisfactory, except for some special types of mills, and a rope drive with a moderate speed motor, in many cases, involved as large an investment as a direct-connected machine.

The improvements made in herringbone gear units have been an essential factor in the development of main roll drives. The flexibility of the gear unit in respect to speed ratios has enabled the motor designer to standardize a line of motors of improved performance and with a resultant reduction in first cost and maintenance expense.

The total horse-power of direct-connected, rope, belt, chain and gear-driven rolling mills, in the United States, is shown in Fig. 1. This data was taken from the Iron and Steel Engineer, January, 1925, issue. Fig. 2 gives the same data by the number of units, instead of horse-power. It is interesting to observe from Tables 1 and 2 that most of the early drives were direct-connected, and rope drives were used to some extent. However, in recent years, only about one-third

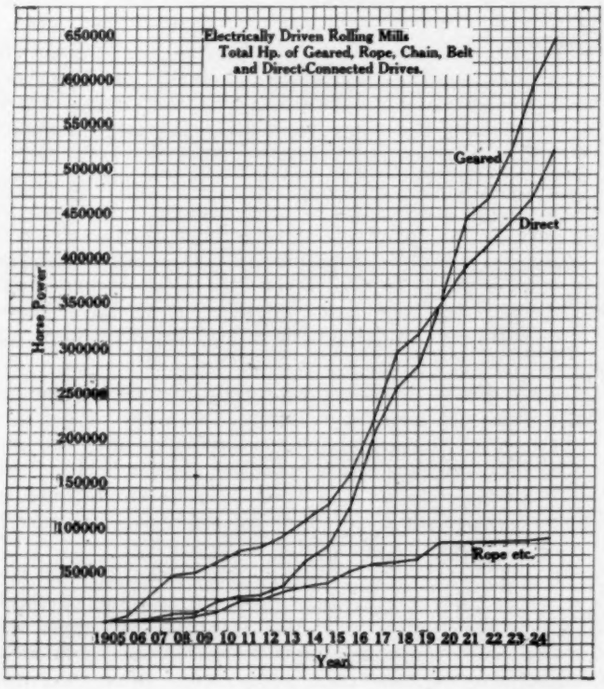


FIG. 1

Curve marked Rope, etc., includes rope, belt and chain drives.

are direct-connected, less than one per cent driven by ropes, chains or belts, while two-thirds of all new installations are geared.

FREQUENCY

A frequency of 25 cycles lends itself favorably to obtaining low motor speeds, together with a relatively good performance, and for the early drives it was selected largely to avoid the installation of speed reduction units. Due to the rapid development and present preponderance of 60 cycle power in this country, many

TABLE 1—ELECTRICALLY DRIVEN ROLLING MILLS

TOTAL HORSEPOWER AND PER CENT RATIO OF DIRECT-CONNECTED, ROPE, BELT, CHAIN AND GEAR DRIVEN MOTORS INSTALLED DURING THE YEARS INDICATED

	Years	Direct H.P.	%	Rope,etc.* H.P.	%	Geared H.P.	%	Total H.P.
	1905	10600	89	1300	11			11,900
	1906-1910	69090	57	21910	18	30300	25	121,300
	1911-1915	99895	43	32200	14	101360	43	233,455
	1916-1920	215420	39	22380	4	320505	57	588,305
	1921-1924	158550	44	1700		203470	56	363,720
#	1921-1924	104550	34	1700		203120	66	309,370

*This column includes rope, belt, and chain drives.

#Same as the preceding line except that reversing motors, which are inherently direct-connected, have been omitted.

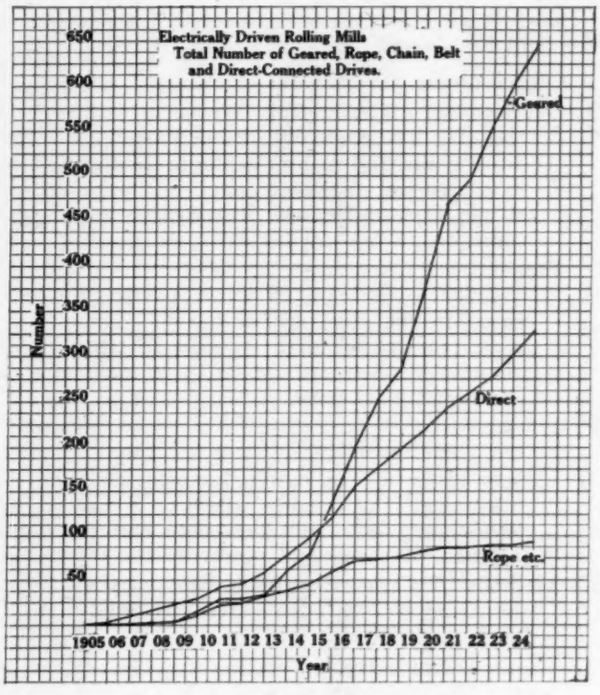


FIG. 2

Curve marked Rope, etc., includes rope, belt and chain drives.

TABLE 2—ELECTRICALLY DRIVEN ROLLING MILLS

TOTAL NUMBER AND PER CENT RATIO OF DIRECT-CONNECTED, ROPE, BELT, CHAIN AND GEAR-DRIVEN MOTORS INSTALLED DURING THE YEARS INDICATED.

	Years	Direct No.	%	Rope,etc.* No.	%	Geared No.	%	Total No.
	1905	5	71	2	29			7
	1906-1910	35	43	20	24	27	33	82
	1911-1915	83	35	39	17	112	48	234
	1916-1920	120	25	26	6	328	69	474
	1921-1924	88	32	3	1	181	67	272
#	1921-1924	78	30	3	1	180	69	261

*This column includes rope, belt and chain drives.

#Same as the preceding line except that reversing motors, which are inherently direct-connected, have been omitted.

cases arose where moderate, or high speed motors had to be used to obtain reasonably good performance and the successful introduction of reduction gears was the deciding factor in making the 60 cycle installations satisfactory.

Fig. 3 shows to what extent different frequencies are used in the rolling mill industry today. Tables 3

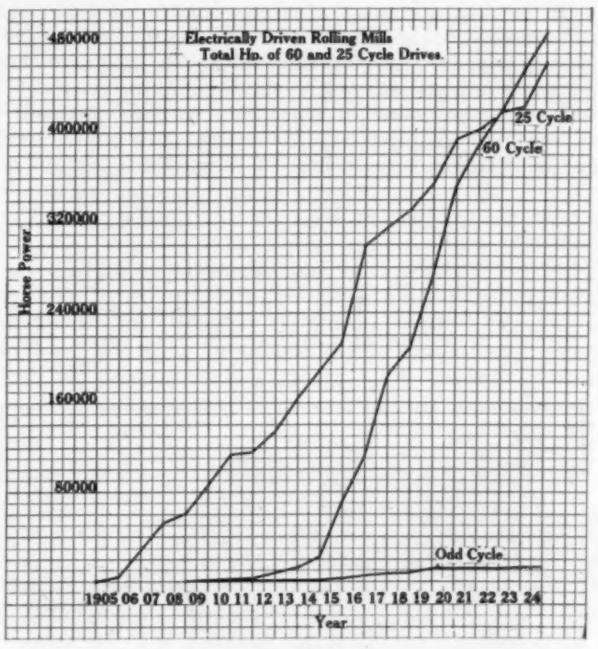


FIG. 3

and 4 show, perhaps more clearly, how rapidly 60 cycle power is gaining in rolling mill plants. At present fully 75 per cent of all new installations are 60 cycles.

TABLE 3—ALTERNATING CURRENT MAIN ROLL DRIVES

TOTAL HORSEPOWER AND RATIO 25 TO 60 CYCLE MOTORS INSTALLED DURING THE YEARS INDICATED.

Years	25 Cycles H.P.	%	60 Cycles H.P.	%	Odd Cycles H.P.	%	Total H.P.
1905	4900	100					4900
1906-1910	110060	97	1950	2	1300	1	113310
1911-1915	99675	57	72610	42	1500	1	173785
1916-1920	179540	38	282265	60	8000	2	469805
1921-1924	67500	34	131740	65	2900	1	202140

TABLE 4—ALTERNATING CURRENT MAIN ROLL DRIVES

TOTAL NUMBER AND RATIO OF 25 TO 60 CYCLE MOTORS INSTALLED DURING THE YEARS INDICATED.

Years	25 Cycles No.	%	60 Cycles No.	%	Odd Cycles No.	%	Total No.
1905	4	100					4
1906-1910	58	89	4	6	3	5	65
1911-1915	95	50	93	49	1	1	189
1916-1920	131	31	275	66	12	3	418
1921-1924	47	23	152	75	5	2	204

With 25 cycle constant speed motors, only a few fixed speeds are available, while with 60 cycle constant speed motors a much greater range of speeds can be obtained. Table 5 shows that between 1200 rpm. and 83 rpm., synchronous speed, 40 different speeds can be obtained with 60 cycle motors, whereas with 25 cycle machines only 17 speeds are available.

TABLE 5

SYNCHRONOUS SPEEDS AVAILABLE BETWEEN 1200 AND 83 R.P.M. FOR 25 AND 60 CYCLE CONSTANT SPEED MOTORS.

	Poles			Poles			Poles	
Speed	60 Cycle	25 Cycle	Speed	60 Cycle	25 Cycle	Speed	60 Cycle	25 Cycle
1200	6		240	30		128	56	
900	8		225	32		124	58	24
750		4	214		14	120	60	
720	10		212	34		116	62	26
600	12		200	36		112	64	
514	14		188	38	16	109	66	
500		6	180	40		106	68	28
450	16		172	42		103	70	
400	18		167		18	100	72	30
375		8	164	44		97	74	
360	20		156	46		95	76	
327	22		150	48	20	94		32
300	24	10	144	50		92	78	
277	26		138	52		90	80	
257	28		136		22	88	82	34
250		12	133	54		83	86	36

POWER FACTOR

On early electrical drives little attention was given to the subject of power factor. At present, however, it receives more careful consideration. This has been due to a closer study of operating costs and need for improvements in power systems. Central stations are giving this subject more attention than in the past, are

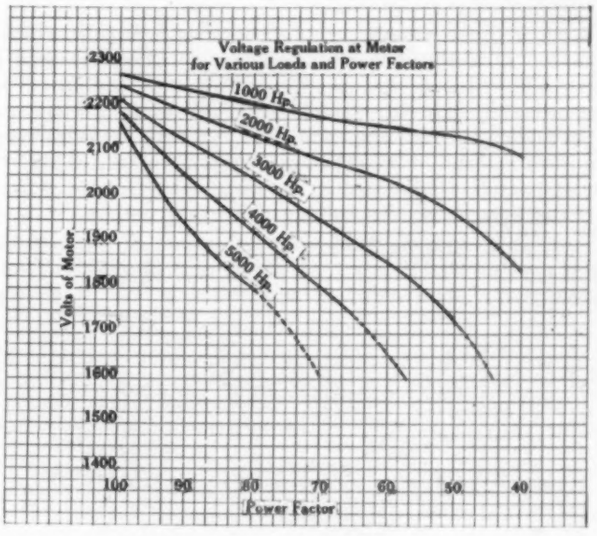


FIG. 4

Voltage regulation over a 13,200 volt, 60 cycle transmission line, six miles long, using 4/0 wire with 54 inch spacing and a 5,000 kva., 13,200/2300 volt step down transformer bank. Voltage assumed constant at supply end of 13,000 volt line. Dotted curves indicate that the kva. load is greater than the capacity of the transformer bank.

charging higher rates for a low power factor and giving a bonus for a power factor above a certain specified per cent.

Low power factor naturally results in the handling of a considerably greater amount of current than is necessary to transmit a given amount of energy. This

needlessly ties up generating and transmission equipment and increases friction losses. Low power factor is robbing many plants of 20 to 30 per cent of their installed capacity.

Even though larger conductors are used to carry the increased current required by a low power factor load, the voltage regulation is never as good as when the power factor of the transmission line is more nearly

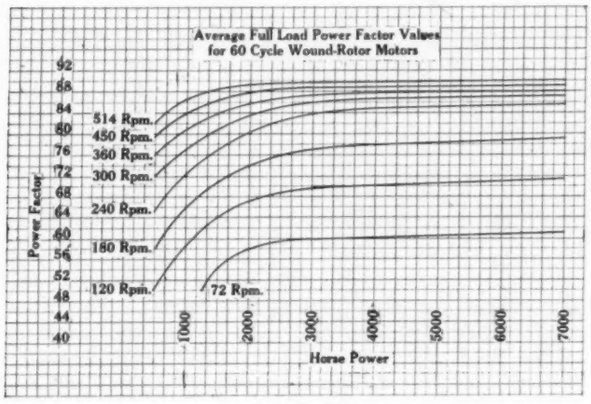


FIG. 5

unity. This is illustrated by the curves in Fig. 4 which indicate the voltage regulation for different loads and different values of power factor. The drop in voltage below the no-load voltage, with a power factor of 100 per cent, represents the best regulation that can be obtained on this particular line.

Poor line voltage regulation also has other drawbacks. If a motor is operated below normal voltage its speed is reduced, its maximum torque is decreased approximately as the square of the voltage drop, and since the current required for a given load increases approximately in direct ratio to the voltage drop, the temperature of the motor increases nearly in proportion to the square of the voltage drop.

It is a rule in practically all types of motors that the greater the number of poles, and consequently the slower the speed, the greater must be the total mag-

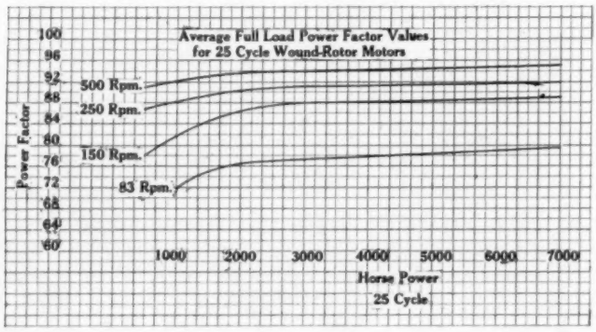


FIG. 6

netizing ampere turns for a given rating. In induction motors the same turns are used for magnetizing and for generating counter e.m.f. The ampere turns necessary for generating counter e.m.f. usually so fixes the number of turns, in a machine of a given capacity and speed, that the actual magnetizing current increases very greatly with any increase in the number of poles—that is, with a decrease in speed. Thus, with a large number of poles, this magnetizing current becomes so large in comparison with the work current that the characteristics of the machine, particularly the power factor, are seriously affected. This increase in magnetizing current can be limited to a certain extent by increasing the dimensions and thereby the cost of the machine, but from the standpoint of power factor, the low speed motor is always at a decided disadvantage.

In a motor having a large number of poles and consequently being a low speed machine, the increased magnetizing current, together with the magnetic leakage, also affects adversely the maximum torque. A relatively high value of maximum torque, however, is an essential requirement for rolling mill applications and necessitates high values of magnetic induction and magnetizing current which, in turn, further reduce the power factor, particularly on the low-speed, direct-connected motor.

Fig. 5 illustrates average power factor values for a wide range of horse-powers and speeds of 60 cycle wound rotor induction motors designed for rolling mill service, and Fig. 6 gives similar data for 25 cycle motors. These are only average values, because the power

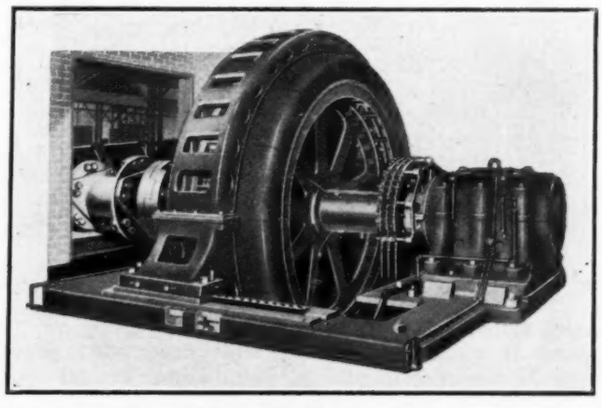


FIG. 7—5,000 HORSEPOWER, 197 R.P.M., 60 CYCLE WOUND ROTOR INDUCTION MOTOR DRIVING A 132 IN. PLATE MILL.

factor for a given rating depends on the maximum torque, air gap, temperature rise and many other factors.

The power factor of a 25 cycle machine of a given rating and moderate speed is 3 to 5 per cent better than that of the corresponding 60 cycle motor. Likewise the power factor of a 25 cycle low speed motor is 10 to 15 per cent better than that of a 60 cycle machine of the same horse-power and speed. This is due to inherent characteristics of the design of the two machines. The 60 cycle motor has a greater number of poles and less active iron than the 25 cycle machine. Consequently the ratio of magnetizing to work current is greater in the 60 cycle motor, with resulting lower power factor.

A comparison of the two curves shows that for a given horse-power and number of poles, the power factor is practically the same for either 25 or 60 cycles. In other words, a 2000 h.p. 20 pole motor has about the same power factor, whether designed for either 25 or 60 cycles. This is due, principally, to the fact that the ratio of the magnetizing ampere turns per pole to the total ampere turns per pole is, approximately, the same for either frequency.

Sixty cycle motors are usually large in diameter and comparatively narrow, while 25 cycle motors have a smaller diameter and greater width. This is illustrated in Figures 7 and 8.

METHODS OF CONNECTING DRIVING UNITS

The relative merits of the various methods of connecting the driving unit to the mill is a broad subject and should include, not only a careful analysis of the mill conditions to be met, but also a review of the characteristics of the driving units. Four principal methods of drive, which might prove suitable, are as follows:

1. Direct Drive.
2. Rope Drive.
3. Chain Drive.
4. Gear Drive.

Combinations of any of these four methods are sometimes used, as in driving a Belgian Mill, where the roughing stand may be rope driven, while the finishing stands are either direct-connected or geared to the motor.

DIRECT DRIVE

Low speed direct-connected induction motors, especially 60-cycle, not only cost more, in most cases, but the electrical performance is poorer than that of higher

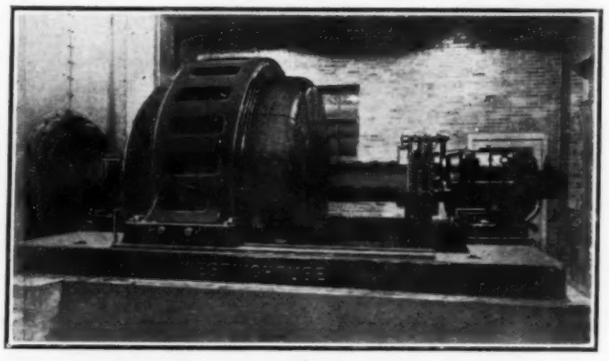


FIG. 8—5,000 HORSEPOWER, 370 R.P.M., 25 CYCLE WOUND ROTOR INDUCTION MOTOR DRIVING A 132 IN. PLATE MILL.

speed machines. Fig. 9 shows a 4000 h.p. 60-cycle, 93 r.p.m. direct-connected wound rotor induction motor. Fig. 10 gives comparative performance curves of two 4000 h.p., 60-cycle wound rotor induction motor, one with 76 poles to give 93 r.p.m. for direct connection and the other with 16 poles to give 440 r.p.m. for use with a gear unit. Fig. 11 gives comparative performance curves of two 6000 h.p. 25 cycle wound rotor induction motors, one with 30 poles to give 98 r.p.m., for direct connection and the other with 8 poles to give 368 r.p.m. for use with a gear unit. The curves show that the efficiency varies so little with speed that it can be neglected as a factor when comparing direct-connected and geared drives.

The power factor, however, varies over a wide range. The low speed motor not only has a considerably lower power factor, but it drops off rapidly at reduced load, so that during light load periods, and between passes when the motor is carrying only the friction load of the mill, the power factor is very poor.

When the average load of a mill is taken into consideration it will be appreciated that the integrated power factor would, for the average load, probably not be higher than the power factor of a motor at 75 per cent load.

CHAIN DRIVE

Chain drive has been used to a restricted extent in the rolling mill industry, usually on merchant and non-ferrous mills. Some of the largest drives placed in

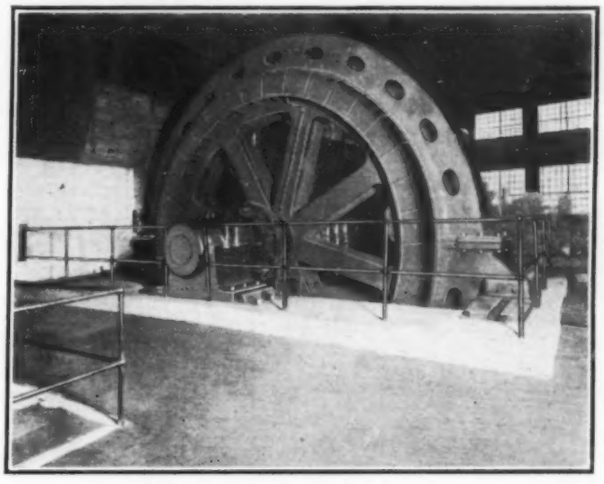


FIG. 9—4,200 HORSEPOWER, 93 R.P.M., 60 CYCLE WOUND ROTOR INDUCTION MOTOR DRIVING CONTINUOUS BAR MILL AT THE UNITED ALLOY STEEL CORPORATION, CANTON, O.

operation, up to the present time, transmit 600 h.p., there being two of these installed in the plant of the St. Louis Screw Company.

The advantages claimed for chain drive are convenience of application, short centers, flexibility, easy repairs, high efficiency and positive speed ratio. It requires less floor space than rope, or belt drive, and costs less than gear drive. It has a high transmission

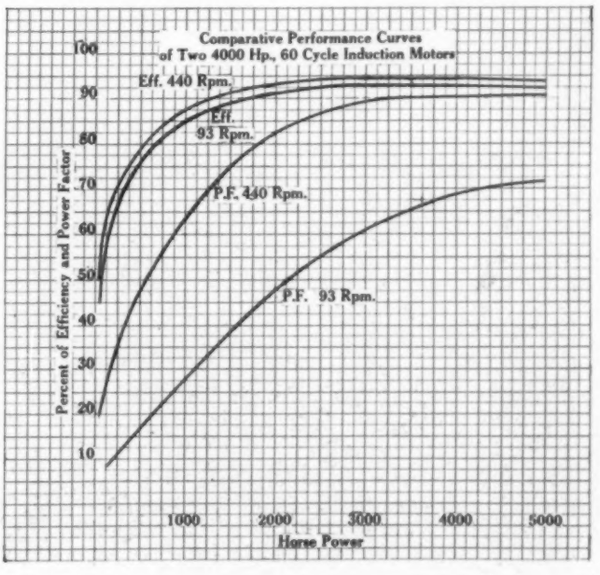


FIG. 10

One with 76 poles to give 93 R.P.M., for direct connection, and the other with 16 poles to give 440 R.P.M. for use with a gear unit.

efficiency and a maximum speed reduction of about 7 to 1.

Obviously, the use of a speed reducing unit is due to the desire to use a motor of fairly high speed. Since the present limiting speeds for chain drives seem to be about 600 r.p.m. for 300 to 400 h.p., 450 r.p.m

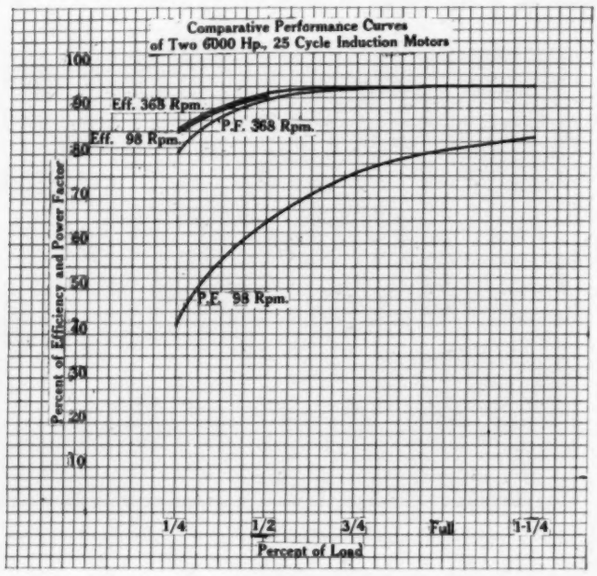


FIG. 11

One with 30 *poles to give* 98 *R.P.M. for direct connection, and the other with* 8 *poles to give* 368 *R.P.M. for use with a gear unit.*

for 500 to 1000 h.p., and 250 r.p.m. above 1000 h.p., its field of application to main roll drives seems to be very restricted.

ROPE DRIVE

Rope drive is being used in the rolling mill industry on existing installations to obtain a restricted degree of speed reduction, the maximum being a 4 or 5:1 ratio, thereby allowing the use of a moderate speed motor.

Today the initial cost of a rope drive is, approximately, equal to that of a gear drive, but the maintenance cost is so high as to be objectionable for any new installation. Another objectionable feature of the rope drive is the space required, which is considerably more than that of a gear drive.

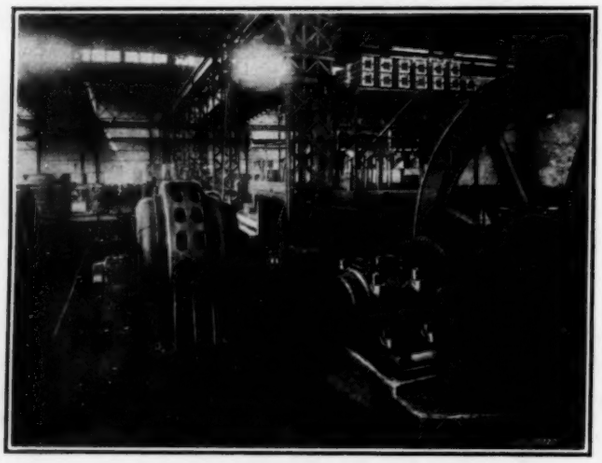


FIG. 12—600 *HORSEPOWER CHAIN DRIVEN MERCHANT MILL AT THE ST. LOUIS SCREW COMPANY'S PLANT, ST. LOUIS, MO.*

BRIEF HISTORY AND DEVELOPMENT OF HERRINGBONE GEARS

A brief review of the early history and development of herringbone gear drives as applied to rolling mill service, may be of passing interest.

The first herringbone gear unit on an electrically driven mill was installed in 1912. This is a 1400 h.p. 7.7 to 1 ratio gear unit driving a sheet mill. The arrangement of the gear is in accord with the conventional drives of today, having fly-wheels on each end of the pinion shaft overhanging the pinion bearings. This first herringbone gear unit operated so well that it was duplicated in 1920 for driving additional sheet and jobbing mills. The general design of this gear drive proved so satisfactory that it has become the approved practice of modern drives. About the same time two 1600 h.p. gear units, without fly-wheels, were installed for billet mill drives.

Since these early beginnings a great number of gear drives has been furnished for various types of

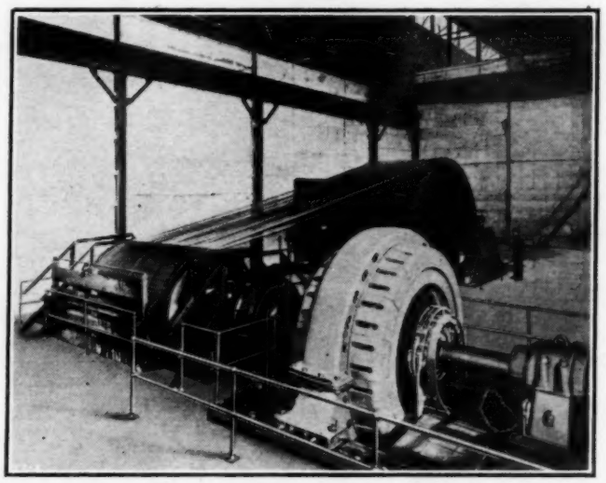


FIG. 13—2,000 *HORSEPOWER ROPE DRIVEN 90 IN. PLATE MILL AT THE INLAND STEEL COMPANY, INDIANA HARBOR, IND.*

mills from the light, high speed drives for rod and merchant mills to heavy, slow speed drives for billet and plate mills.

There has been little, if any, change in general principles, but development has resulted in important refinements of construction, including increased accuracy in the cutting of gears, careful balancing of all running parts, and the perfection of lubricating systems and methods of meeting the requirements of different types of mills.

The most interesting illustration of a high speed, large capacity herringbone gear unit is at the Ensley rail mill of the Tennssee Coal, Iron & Railroad Company. This is a 5,000 h.p. gear unit, with balanced fly-wheels on the pinion shaft, driven by a 600 r.p.m. motor, the mill operating at 95 r.p.m. The drive was furnished in 1922, and was then regarded as a somewhat radical departure from accepted practice. This

gear unit has been operating for two years and is one of the quietest and smoothest running gear units in operation. Its condition today is practically the same as when it was first installed, and there is every indication of long life for this exceptionally high speed unit, which has gear speed of about 4000 ft. per minute.

Another illustration of large capacity, high speed, gear drives is at the South Chicago Works of the Illinois Steel Company, where two 5000 h.p. gear units, with balanced fly-wheels on the pinion shaft are driving 132 in. and 90 in. plate mills, respectively. These gear units are driven by 370 r.p.m. motors and have 5.3 to 1 reduction.

Many gear units have been in operation more than ten years with no appreciable wear, indicating that they will be satisfactory for long years of service.

The progress in herringbone gear development has been rapid and it is interesting to observe the rate at which the use of geared units is increasing. Even as recently as five years ago there was considerable difference of opinion in regard to the two methods of

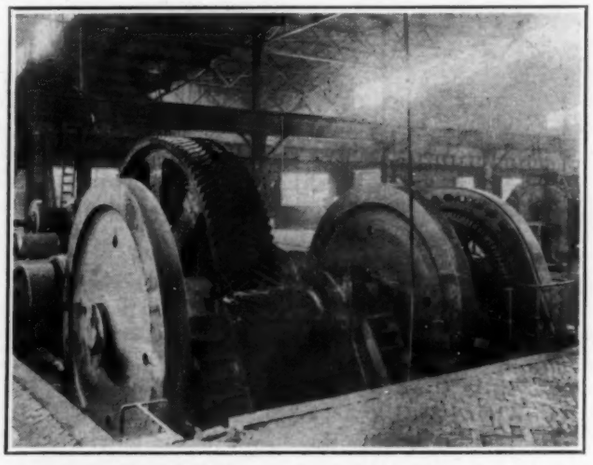


FIG. 14—1,800 *HORSEPOWER, 7.7 TO* 1 *RATIO HERRINGBONE GEAR UNIT DRIVING SHEET MILL AT THE APOLLO STEEL COMPANY, APOLLO, PA.*

The illustration shows a duplicate of the first motor driven sheet mill gear unit with balanced overhung fly wheels.

drive, but at present there seems to be a more general application of gear units for main roll drives. It is true that gear units are still installed which do not perform according to expectations, but there seems to be a sufficient number operating successfully to indicate that gear units can be selected the maintenance of which will be so small as to be comparable to that of the motor.

The normal speeds of rolling mills are usually such that the reduction below the speed of any ordinary high speed induction motor can be adequately handled by a single reduction unit. Double reduction units require greater care in manufacturing and maintaining proper alignment and, there is also an additional set of gears and bearings to maintain. There are, however, cases where double reduction units can be applied with advantage. A few installations have been made for the purpose of obtaining more than one speed on the mill by mounting two or more pinions in the same box and sliding the motor on rails for coupling to one pinion or another, as desired. In general, gearing to be successful should be kept as simple as possible.

LUBRICATION

Long life and high efficiency cannot be expected in any machine without proper lubrication. This is especially true of gear reduction units. More trouble has

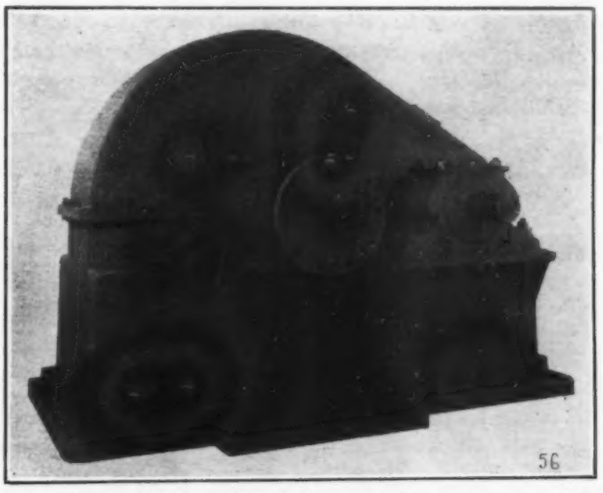


FIG. 15—*EARLY HERRINGBONE GEAR UNIT WITHOUT FLYWHEELS.*

This 1600 *horsepower gear unit driving billet mill was installed in* 1912.

been experienced on earlier gear units because of inadequate or improperly conceived methods of lubrication, than from any other cause.

Except for the elasticity of the metal of the tooth surfaces, the contact between the teeth is theoretically that of line contact. It is evident, then, that the maintenance of the lubricating film between the tooth sur-

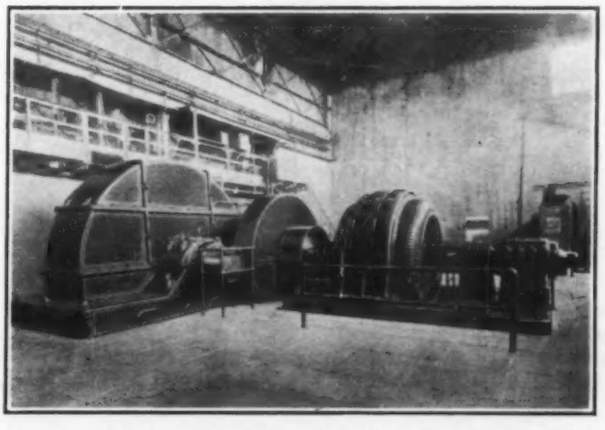


FIG. 16—5,000 *HORSEPOWER, 600 R.P.M., GEAR UNIT WITH BALANCED FLYWHEELS ON THE PINION SHAFT DRIVING THREE STAND 28 IN. RAIL MILL AT THE TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM, ALA.*

This is the largest high speed gear unit in this country.

faces is an essential, though difficult matter. The breaking down of this film, allowing metal-to-metal contact, will soon result in tooth wear. A lubricant of sufficiently high viscosity to maintain this film is a necessity.

For heavy duty gears, where high tooth pressures prevail, such as for blooming, billet and plate mills, a lubricant of high viscocity is required. For merchant and other relatively higher speed light duty mills, a lubricant of considerably lower viscocity is preferable.

It seems that not only the proper kind of lubricant, but also the proper level and amount of lubricant are essential for successful drive.

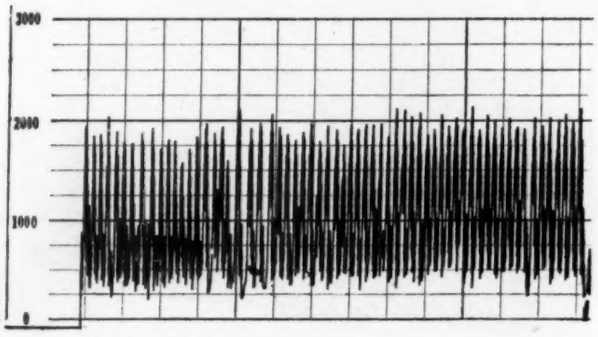


FIG. 17—POWER CHART OF A PLATE MILL WITH SUFFICIENT FLYWHEEL EFFECT.

IMPORTANCE OF ACCURATE ALIGNMENT

On early steam engine installations correct alignment was of relatively small importance because misalignment was readily taken care of by the coupling, due to the low engine speeds then in use. With low speed, direct-connected motors comparatively little trouble has been experienced from misalignment. With the use of higher speed motors, however, the question of proper alignment has become more important, and a number of troubles on geared driving units has been traced to lack of appreciation of the importance of maintaining proper alignment.

COUPLINGS

A good, flexible coupling will compensate for a certain amount of misalignment, and the selection of a suitable coupling, therefore, becomes an important consideration.

The importance of the coupling as a connecting link increases greatly with the speed of the motor. On some low speed, properly aligned motor drives, rigid couplings are giving satisfactory service. With higher speed motors and particularly with gear drives, proper flexible couplings are, in most cases, essential for successful operation.

The use of herringbone gears imposes special restrictions on couplings because, for best service, the herringbone gear and pinion should not move sidewise independently of each other, even though the displacement of either be but very slight and momentary.

When fly-wheels are mounted on the pinion shaft of a herringbone gear-drive, the coupling between the motor and gear-drive may materially assist in bringing about successful operation of the whole driving system for the following reasons:

Seemingly the "V" action of herringbone gears under load assures positive contact on both helices, and again, seemingly, it would require a force proportional to tooth load and helical angle to disturb the engagement of pinion and gear when running under load. Actually, however, such is not the case as a comparatively light pressure will suffice to shift the tooth load entirely to one helix for an instantaneous period, and with endwise movement of the pinion which may be very slight indeed. What follows, then, is a rather complicated set of reactions which result in endwise oscillation of the pinion, which, it must be remembered, carries with it the fly-wheels. If the external pressure on the pinion shaft ceases, the gears will again divide the tooth load equally on both helices and run smoothly until such time as the external force again acts on the pinion shaft. The foregoing is largely due to the use of fly-wheels mounted on the pinion shaft, because of the great inertia thereby added to the pinion.

In this state of oscillation, tooth pressures and the manner of contact are abnormal to an extreme degree, and when present may account for unduly rapid wear of the herringbone pinion, and to a lesser extent, of the gear. Shock and vibrations transmitted to the motor and its bearings through a stiff or improperly designed coupling may also constitute a menace to the motor. All of these things can be compensated by properly selected couplings.

With some types of couplings, lubrication is of first importance and should be checked up as carefully as any part of the main lubricating system.

The capacity of a coupling for compensating misalignment is essential to a successful operation of higher speed drives because a certain amount of misalignment is inevitable in steel mill service, though it be but temporary. It should be remembered that a coupling, which will function fully when in fair alignment, has its value reduced by an exceptional degree of mis-alignment; that is to say, the torque transmitted is not equally distributed as load upon the working parts of the coupling.

An ideal coupling should be fully extensible. It should be able to take care of some mis-alignment. It

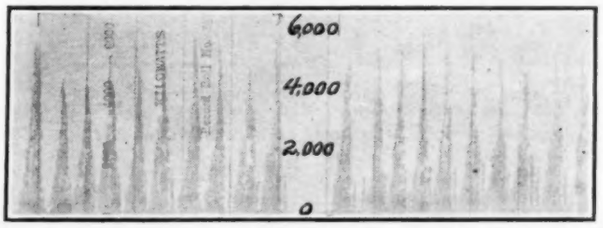


FIG. 18—POWER CHART OF A PLATE MILL WITH INSUFFICIENT FLYWHEEL EFFECT.

should be torsionally flexible, that is, it should provide cushion effect and it should prevent end thrust on the motor shaft, as well as on the driving shaft.

FLY-WHEEL EFFECT

With our present day knowledge of rolling mill requirements, the proper fly-wheel effect needed can readily be determined.

When the peaks are excessive, that is, beyond the pull-out range of the motor, which usually is two to two and one-half times the full load of the motor, or when the load is of such a fluctuating character that it is desirable to equalize it, a fly-wheel can, generally,

be used to an advantage. For instance, the early passes in a plate mill may require four to five times the power of the motor for a fraction of a second. For such a condition a suitable control can be arranged so that the motor will take a certain proportion, and the fly-wheel supply the remainder. The peaks are reduced when the passes become longer, and the motor then carries a greater proportion of the load. By close study of load conditions an economical balance can be established.

Theoretically, the stored energy in the fly-wheel should be such that the motor would carry only the average load, the fly-wheel giving up its energy when the rolling load exceeds the average, and having energy stored in it by the motor when the rolling load is below the average. However, in actual practice this condition is seldom attained. In a great number of cases, especially in direct connected motor drives, it would require an excessively heavy fly-wheel or too great a drop in speed to completely equalize the load.

To obtain the maximum output of the mill it is necessary to have adequate fly-wheel effect and proper continuous capacity of the motor. A number of installations have been made where, by keeping these

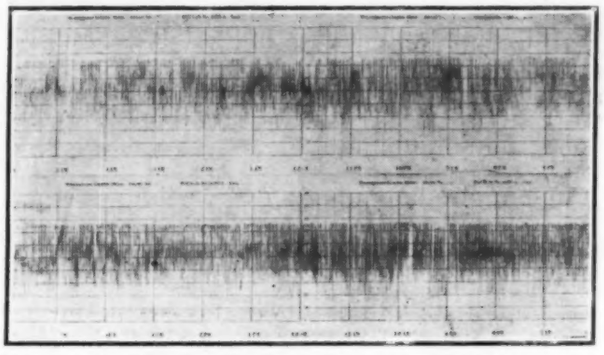


FIG. 19—POWER INPUT TO THE WOUND ROTOR INDUCTION MOTOR DRIVING THE FLYWHEEL SET ON A REVERSING BLOOMING MILL.

points in mind, the tonnage output of the mill has been increased 10 to 25 per cent with no other change.

Figures taken from tests made on two similar plate mills, each rolling 88 in. material, may better illustrate the advantages of the proper fly-wheel effect. Fig. 17 shows a few hours' run on a plate mill having sufficient fly-wheel effect. Fig. 18 shows a curve taken on a similar sized plate mill with insufficient fly-wheel effect. Both of these mills are driven by motors of the same size. It will be seen that in Fig. 17 the peaks are only about one-half those shown in Fig. 18. The result of insufficient fly-wheel effect, and lack of suitable secondary control, is to cause frequent mill interruption, due to the circuit breaker opening on the heavy overloads.

Fig. 19 represents the input to the wound rotor induction motor driving the fly-wheel set on a reversing blooming mill, and clearly shows to what extent power input fluctuations can be limited with the proper combination of suitable motor, fly-wheel effect and secondary control.

FLY-WHEELS

The method employed to obtain adequate fly-wheel effect is an important consideration. Fly-wheels in rolling mill service may be placed in one of the following five locations:

1. In the rotor of the electric motor.
2. On the motor shaft.
3. On its own shaft and bearings operating at mill speed.
4. On its own shaft and bearings operating at motor speed.
5. On the gear pinion shaft.

Only a limited fly-wheel effect can be put into the rotor and even with increased rotor diameter, the fly-

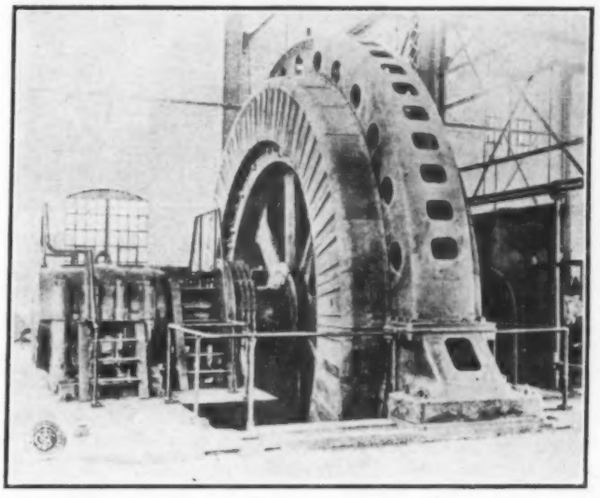


FIG. 20—7,000 HORSEPOWER, 82 R.P.M., DIRECT-CONNECTED MOTOR IN WHICH THE FLYWHEEL EFFECT IS PLACED IN THE ROTOR.

wheel effect obtainable usually is insufficient for the mill load requirements. This method requires a very special expensive motor. Fig. 20 shows a 7000 h.p. 82 r.p.m. direct connected motor in which the fly-wheel effect is placed in the rotor.

If it is desired to combine the motor and the fly-wheel, a better method is to place a separate fly-wheel on the motor shaft. Fig. 21 shows a 4000 h.p., 83

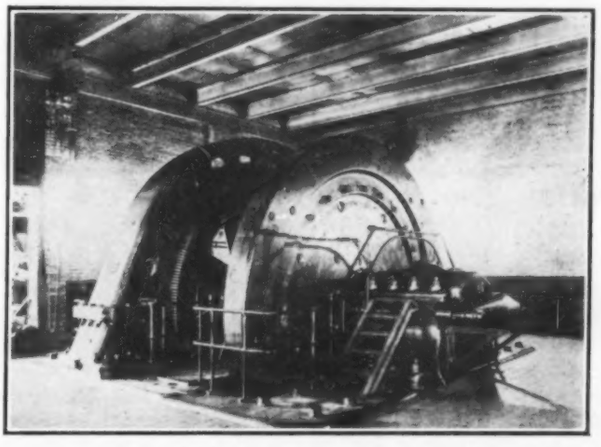


FIG. 21—4,000 HORSEPOWER, 83 R.P.M., GENERAL ELECTRIC INDUCTION MOTOR WITH THE FLYWHEEL ON THE MOTOR SHAFT DRIVING 110 IN. PLATE MILL AT THE CARNEGIE STEEL COMPANY, HOMESTEAD PLANT.

r.p.m. induction motor with the fly-wheel on the motor shaft. This involves a special design of mechanical parts and it is important on such installations that the shaft and bearings be extra liberal in their design. With this construction, added burden, in the form of extra mechanical parts, is placed in the electrical ma-

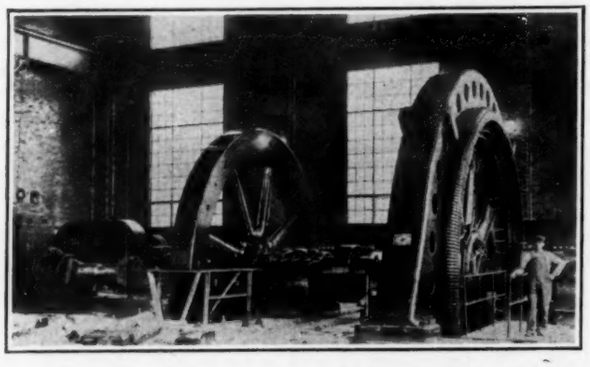


FIG. 22—4,000 HORSEPOWER, 82 R.P.M., GENERAL ELECTRIC INDUCTION MOTOR WITH COUPLED FLYWHEEL DRIVING 110 IN. PLATE MILL AT THE TENNESSEE COAL, IRON & RAILROAD COMPANY, FAIRFIELD, ALA.

chine. Another disadvantage of having the fly-wheel on the motor shaft is that in case any repairs are required on the rotor, the weight and location of the fly-wheel may make handling and repairing difficult.

The third method is to arrange the fly-wheel on a separate shaft, as an extension of the mill driving shaft, to have it mounted in separate bearings, and connected to the drive by means of a flexible coupling. In this case the motor shaft is not in any way affected by wear of the fly-wheel bearings. This method utilizes a motor of standard design, and repairs to the motor

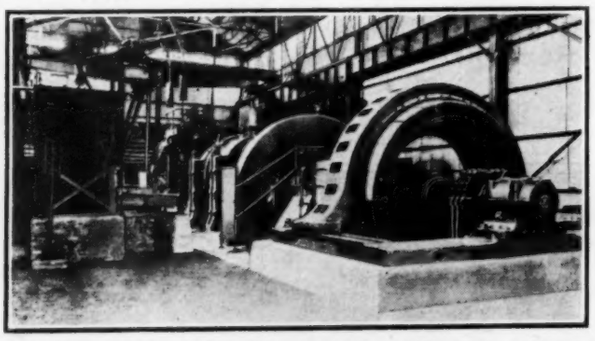


FIG. 23—3,000 HORSEPOWER, 235 R.P.M. MOTOR COUPLED TO FLYWHEEL DRIVING 100 IN. PLATE MILL THROUGH KENNEDY PINION HOUSING AT THE NATIONAL ENAMELING AND STAMPING COMPANY, GRANITE CITY, ILL.

are simplified, since the fly-wheel can be completely isolated at the coupling. When the fly-wheel is placed between the motor and the mill on its own bearings, the fly-wheel takes the peaks before they reach the motor, which is an advantage, as abnormal loads sometimes occur because of broken spindles, or something getting caught in the rolls. Fig. 22 shows a 4,000 h.p. motor coupled to a separate fly-wheel, operating at mill speed on its own shaft and bearings.

The fourth method is to place a high speed fly-wheel, operating at motor speed, on its own shaft and bearings. This method is used for many applications, especially for heavy duty, low speed mills, where manufacturing facilities impose such limits on the diameter and weight of the low speed fly-wheel that it is not always practicable to obtain the desired fly-wheel effect. In such cases considerably greater fly-wheel effect can be obtained by operating the fly-wheel at the motor speed. Also the initial cost can often be materially decreased. A single fly-wheel mounted on separate bearings and located between the motor and the drive pinion, is the original arrangement for the high speed fly-wheel. Fig. 23 shows a 3000 h.p. motor coupled to a high speed fly-wheel. Another arrangement consists of two fly-wheels placed on the pinion shaft of the gear unit. This arrangement, which is shown in Fig. 24, is now used in nearly all the more recent fly-wheel gear drives.

Either cast steel or plate wheels can be used when they are placed on the gear pinion shaft and any de-

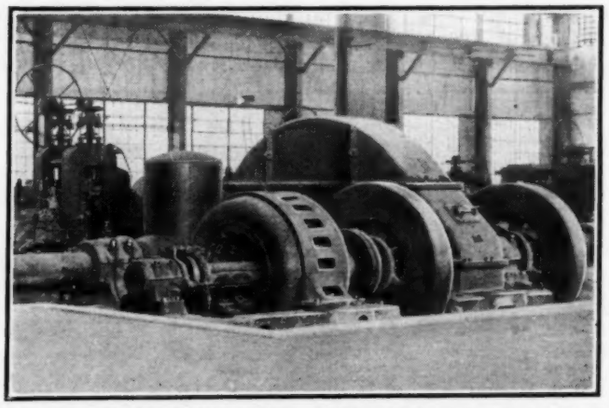


FIG. 24—1,500 HORSEPOWER, 705 R.P.M., GEAR UNIT DRIVING HOT STRIP MILL AT THE WEST LEECHBURG STEEL COMPANY, LEECHBURG, PA.

sired fly-wheel effect can be obtained with light weight fly-wheels, because of the higher speed, since the fly-wheel effect varies as the square of the speed.

To provide for unusual stresses which might occur, it is advisable to include a mechanical fuse of some design. This is usually built into one of the mill spindles. Some recent designs of flexible couplings have incorporated this mechanical fuse feature.

CONTROL

Having provided proper fly-wheel effect, the next point is to make provision for properly utilizing it. Careful consideration should, therefore, be given to the selection of the most suitable type of control. For wound rotor induction motor drives, three methods of utilizing this fly-wheel effect are in use at present.

1. Magnetic secondary control with a fixed slip resistance.
2. Magnetic secondary control with variable slip resistance.
3. Liquid slip regulator secondary control.

Fig. 25 is a load curve on a mill driven by a wound rotor induction motor, having a fixed amount of slip resistance in its secondary at all times. With this type of control the speed of the motor drops off in direct proportion to the load. In other words, if the

mill is operating at light load, any increase in the load would cause the speed of the motor to decrease in proportion to the amount of external slip resistance. This method does not utilize the fly-wheel to its best ad-

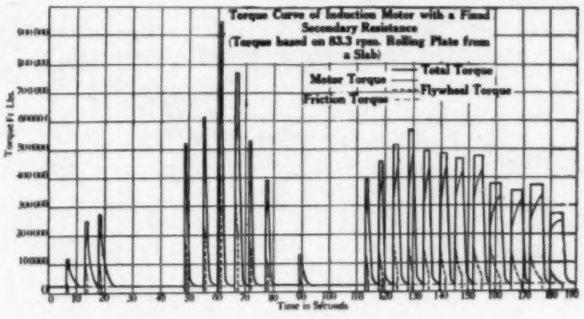

Torque Curve of Induction Motor with a Fixed Secondary Resistance
(Torque based on 83.3 rpm. Rolling Plate from a Slab)
Total Torque
Motor Torque
Flywheel Torque
Friction Torque
Time in Seconds

*FIG. 25**

vantage, as the fly-wheel should not be called upon to give up energy until the motor has first been fully loaded. The ideal condition is to have the speed of the equipment remain at light load speed until the motor is carrying full load, and any load beyond this value should be taken by the fly-wheel. The fly-wheel is installed as reserve capacity, and its energy should

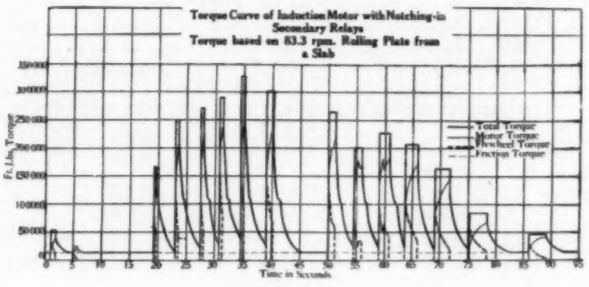

Torque Curve of Induction Motor with Notching-in Secondary Relays
Torque based on 83.3 rpm. Rolling Plate from a Slab
Total Torque
Motor Torque
Flywheel Torque
Friction Torque
Time in Seconds

*FIG. 26**

be conserved as long as the motor is not loaded, otherwise, this reserve capacity must be unnecessarily large.

An improvement on this method is made by the use of a combination of fixed and variable amounts of slip resistance. With this type of control, a fixed amount of resistance is placed in the secondary, of say, 5 per cent, for example. When the motor reaches its

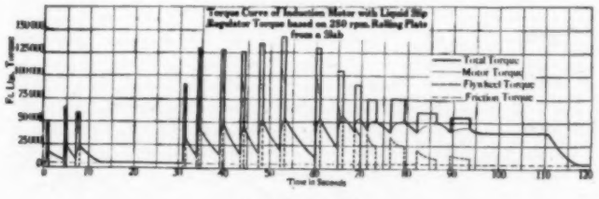


*FIG. 27**

full load, additional resistance is inserted in the rotor circuit so that the fly-wheel is called upon to carry a greater proportion of the peak load. A number of such equipments were installed several years ago, but it was found that the additional slip resistance was not inserted quickly enough to ward off the peaks, and that continual interruption of the secondary current increased the maintenance on the contactors so much that

*Figures 25, 26 and 27, together with the explanation is taken from Mr. G. E. Stoltz's article "Electrically Driven Plate Mills." A. I. & S. E. S. 1918 proceedings.

as a rule the operator arranged the control with a fixed amount of resistance in the secondary circuit. Figure 26 graphically shows the load on a mill equipped with this type of control with the relays set to operate at 175,000 ft. lbs. torque. On the ninth pass, they did

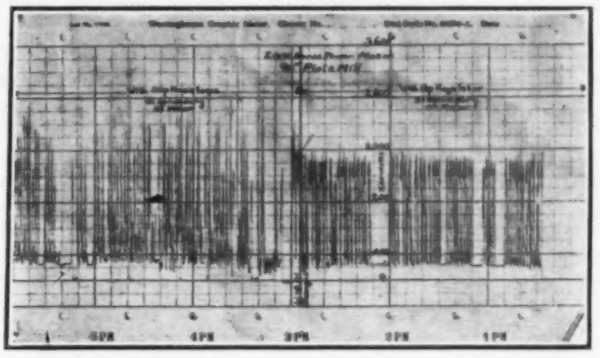


FIG. 28—GRAPHIC CHART ON 90 IN. THREE HIGH PLATE MILL.

not operate until a load of 200,000 ft. lbs. torque was obtained. From an inspection of the motor torque curves during passes 4 to 8 it would seem that the relays did not operate, but these particular passes were actually so heavy that the relays operated immediately upon the introduction of the metal, and the initial swing of the meter was so rapid that the effect of the additional slip could not be detected.

Figure 27 is a load curve on a mill driven by a wound rotor induction motor having a liquid slip regulator in its secondary circuit. This is an improvement over the preceding methods, as it more nearly approaches the ideal condition of conserving the fly-wheel effect until the motor is fully loaded, and at the end of the pass working the motor to capacity until the fly-wheel has been returned to its normal light load speed.

It is the function of the slip regulator to so adjust the resistance in the secondary circuit of the induction

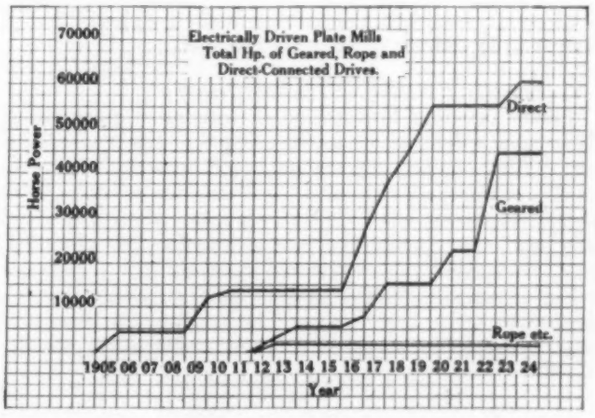


FIG. 29

motor that, during period of heavy loads, the speed of the motor is decreased and the fly-wheel allowed to give up its energy, and, during periods of light load the speed of the motor is increased and energy is stored in the fly-wheel.

Figure 28 is a graphic chart taken on a 90 in. 3 high plate mill showing the k.w. input over a period of 5½ hours. This mill was originally installed with

magnetic secondary control using "notch-back" relays with resistance in the secondary. Later it was found desirable to install a liquid slip regulator and the wiring was arranged so that either the magnetic control or the liquid slip regulator could be connected to the secondary. The motor was operated for the first 2½ hours of the test run with the liquid slip regulator. The peak loads can be seen to follow a straight line a little below 2000 k.w. with only a few momentary loads going slightly above 2000 k.w. The uniform demand for power upon the central station is clearly shown. At 3:00 P. M., the secondary was transferred to magnetic control. The irregular action and resultant variation in input is shown by the chart, some loads going off the scale at 3600 k.w. It is evident from the many advantages of having uniform power input, that the slip regulator control is more suitable than magnetic control for mill applications requiring fly-wheel effect, re-

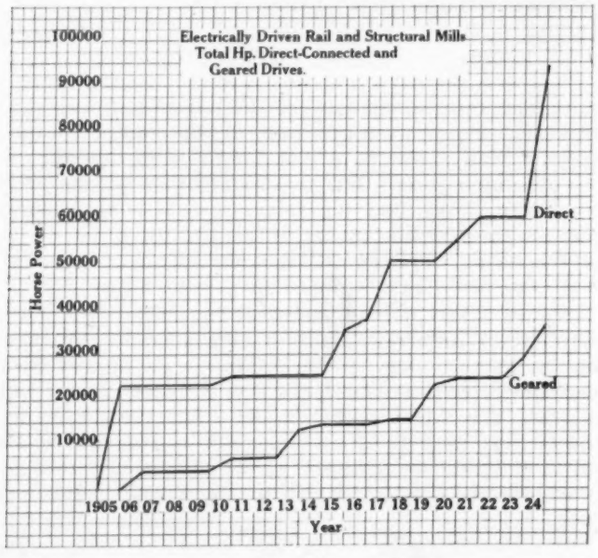


FIG. 30

gardless of whether the motor and fly-wheel are directly connected or geared to the mill.

MAINTENANCE

From the consideration of maintenance expense, the advantages might seem to be with the direct connected unit. Low speed direct-connected motors, however, usually require a relatively large number of coils, some machines having been built with more than 1500 coils each, and the chances of insulation failure, obviously, must be considerably greater in such machines, than in higher speed, geared motors having, approximately, one-fourth as many coils. The maintenance expense required by either type of drive is surprisingly small.

STANDARDIZATION

Low speed direct-connected drives generally involve a special design of motor for each application. The introduction of geared drives has contributed greatly toward the standardization of rolling mill motors thereby effecting a reduction in both the first cost and the maintenance expense. The reduction in first cost comes from the use of duplicate designs whereby the time and expense of making new designs, patterns and tools is eliminated. The reduction in maintenance comes from the lessened stock of spares which must be carried to insure the desired continuity of operation. In fact, it is possible to secure greater insurance of continued operation at less cost for, where a number of duplicate units are in use carrying completely assembled parts, such as a rotor on its shaft, is quite practicable.

Conditions may even be such that carrying a completely assembled spare motor would not be overly ex-

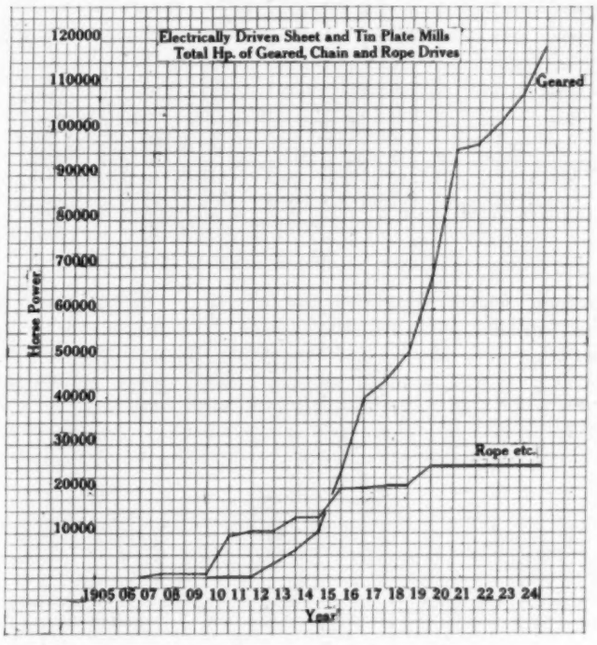


FIG. 31

pensive. Such provisions, of course, are only justified when the idea of standardization is completely carried out.

COST OF INSTALLATICN

At present the cost of the initial installation is weighed more carefully than has been the practice in the past, and if the installation of a motor with gear provides a considerable saving over the cost of a direct-connected motor, the former is usually selected. The relative cost of the two methods depends largely on

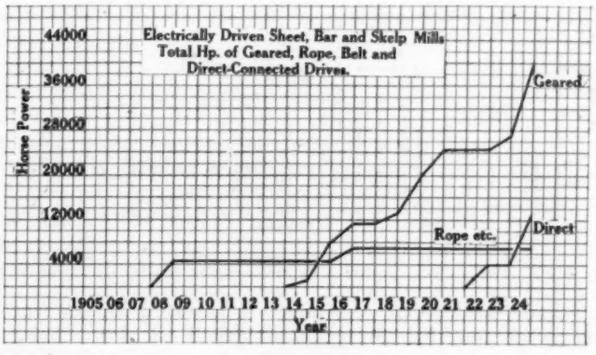


FIG. 32

the gear ratio and unless this is in excess of 3 to 1, gear drive is seldom justified if only the first cost is considered. When the gear ratio can be somewhere between 4 to 1 and 10 to 1, geared equipments usually are cheaper than direct-connected units. In some instances higher ratios than this have been considered, but it is unusual to find an installation where the ratio

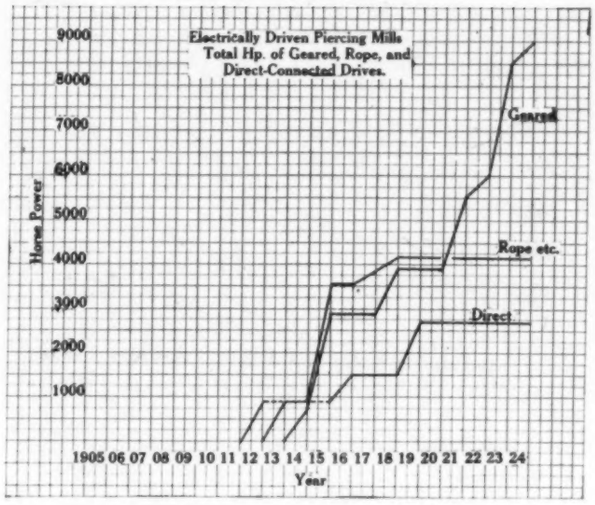


FIG. 33

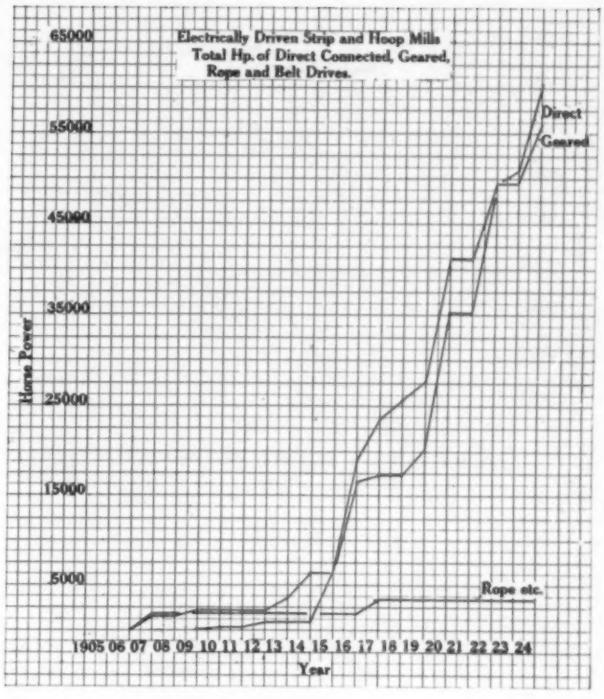


FIG. 34

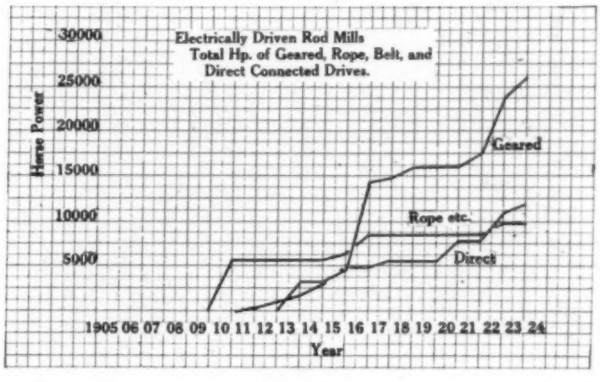


FIG. 35

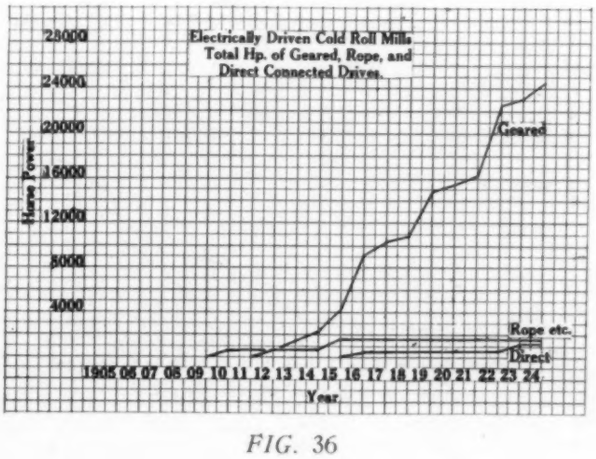


FIG. 36

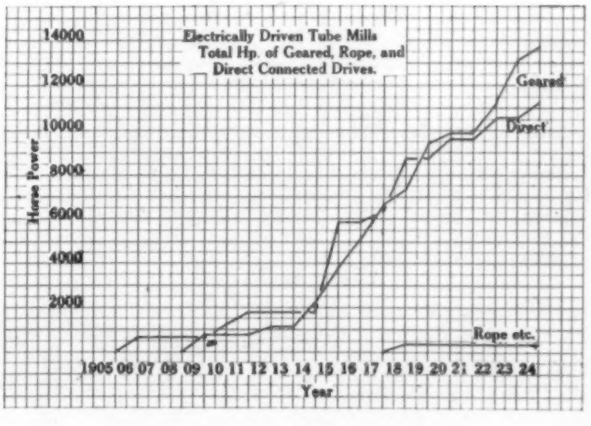


FIG. 37

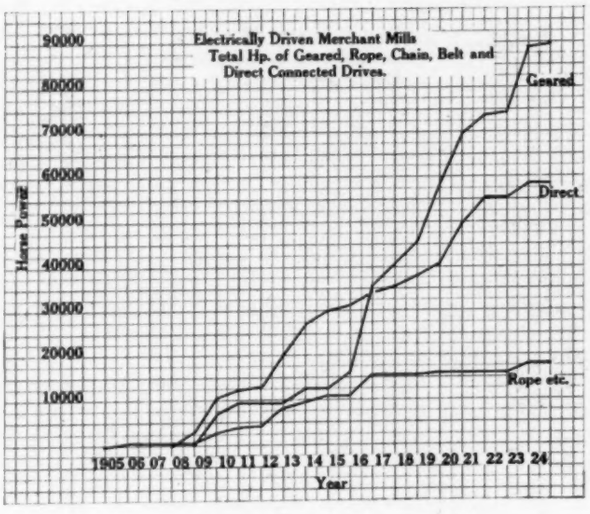


FIG. 38

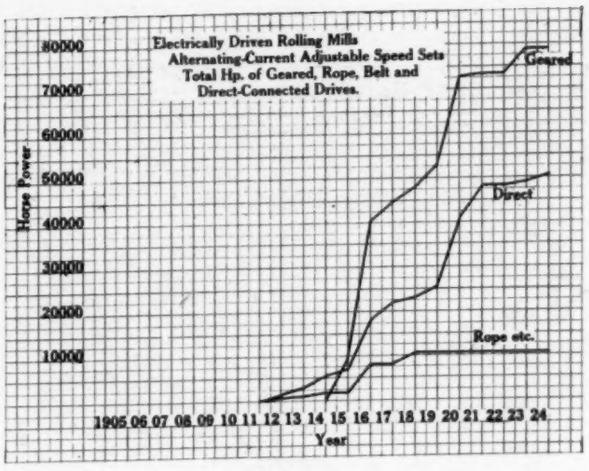


FIG. 39

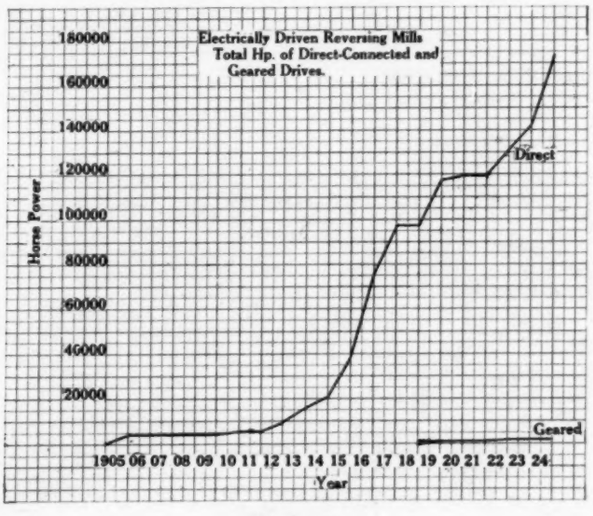


FIG. 40

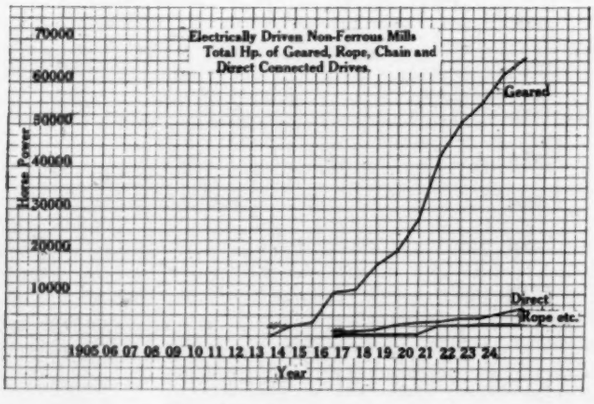


FIG. 41

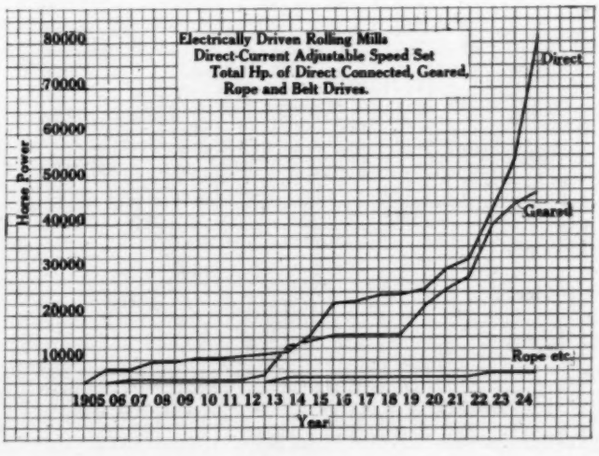


FIG. 42

is materially in excess of 10 to 1, for single reduction and 24 to 1 for double reduction. Comparative first costs and gear ratios are considered at greater length in a later paragraph.

Figs. 29 to 44, inclusive, show clearly the rate at which the use of geared units is increasing. It is evident that geared drives predominate in nearly every type of mill with the exception of large reversing mills

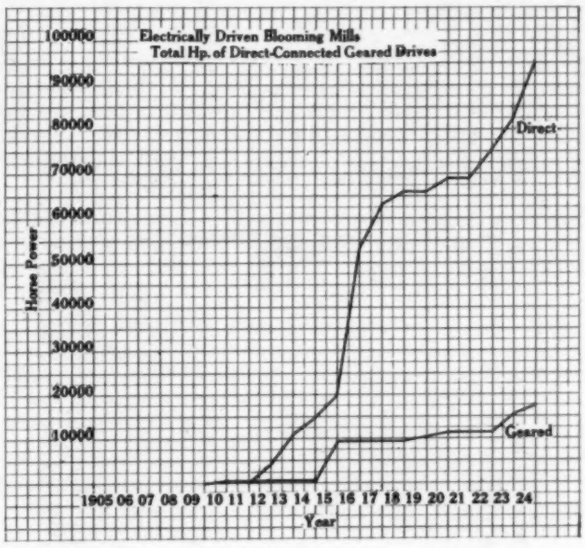


FIG. 43

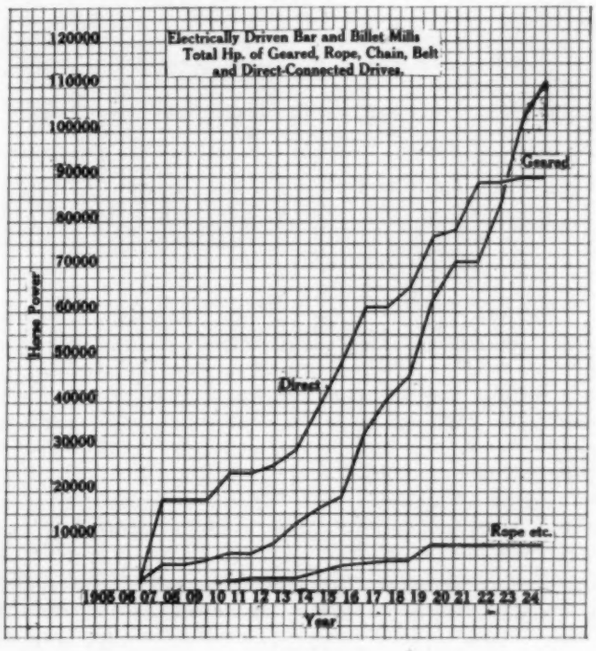


FIG. 44

which are driven by slow-speed direct-current motors. Even the merchant mills, which operate at fairly high rolling speeds, are gear driven to a large extent. The former practice of many operating men to apply direct-connected motors wherever possible, is giving way to more careful study and analysis of not only the first cost, power factor and floor space required, but also of other factors which have a bearing on the operation.

COMPARISON OF TYPICAL MILLS

In the preceding paragraphs, the writer has presented for your consideration many of the factors involved in any main roll drive electrification. These factors have dealt with fundamentals, and at best will serve only as a general guide. In order, however, to enable the steel mill engineer to better analyze the various methods used for driving different types of rolling mills and the relative merits of each, a more

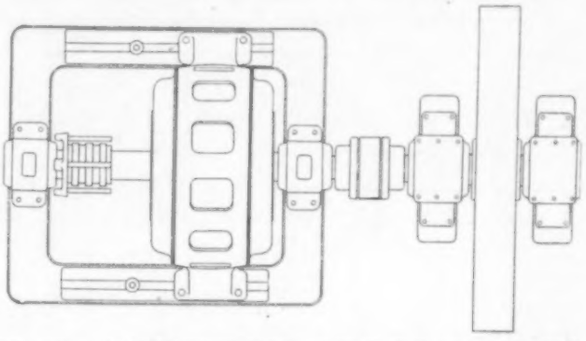


FIG. 45—ALTERNATING CURRENT MOTOR WITH DIRECT CONNECTED, SLOW SPEED FLYWHEEL.

detailed study of representative types of rolling mill drives will be considered from the standpoint of first cost, performance and floor space required.

POWER REQUIREMENTS

The determination of the correct size of motor has to be made for each individual installation after completing a detailed study and careful analysis of the rolling schedules, the kind of material to be rolled, and the other factors involved. While it is true that practically every type of mill has been electrified, these installations serve only as a general guide in making estimates of the capacity of the motor to be installed on a new mill. It is only by following the procedure suggested above that the capacity required can be determined.

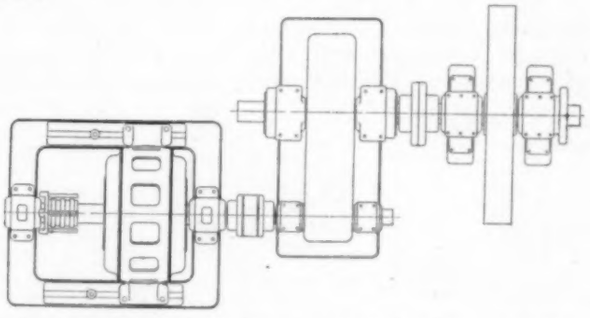


FIG. 46—ALTERNATING CURRENT MOTOR WITH GEAR UNIT AND FLYWHEEL DIRECT CONNECTED TO SLOW SPEED SHAFT.

PLATE MILLS

Most of the Plate Mills in this country are three high mills, of the Lauth design, driven by alternating current, wound rotor type constant speed induction motors.

In considering plate mill drives, we have four methods to choose from:

The first is to connect the motor directly to the fly-wheel shaft through a flexible coupling and connect the fly-wheel shaft to the lead spindle through a mill coupling. Fig. 45 illustrates this type of mill.

The second is to use a motor and a gear unit with the fly-wheel located between the slow speed shaft of the gear unit and the pinion housing. Fig. 46 illustrates this type of mill.

The third is the same as the second except to have balanced fly-wheels located on the high speed

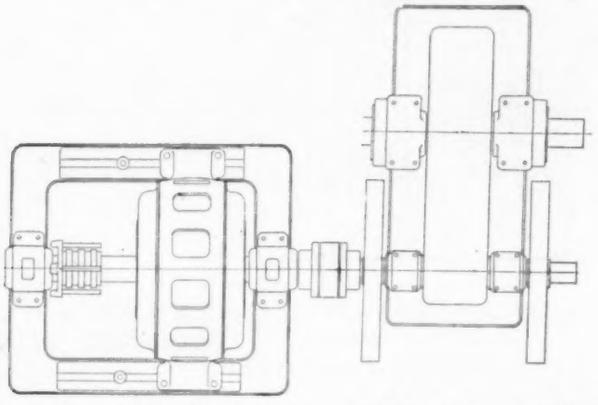


FIG. 47—ALTERNATING CURRENT MOTOR WITH GEAR UNIT HAVING BALANCED FLYWHEELS ON THE PINION SHAFT.

shaft of the gear unit. This arrangement is shown in Fig. 47.

The fourth is to replace the old pinion housing with a modern Kennedy type pinion housing. The fly-wheel is then placed between the motor and the Kennedy pinion housing, the same as in the first method. This, of course, permits the use of a moderate speed motor and a higher speed fly-wheel than is possible with the first method. This type of mill is shown in Fig. 48.

Table No. 6 gives the horsepower, roll speed and fly-wheel horsepower seconds which represent good average values and will serve very well for purposes of comparison. Roll and pinion speeds given are within

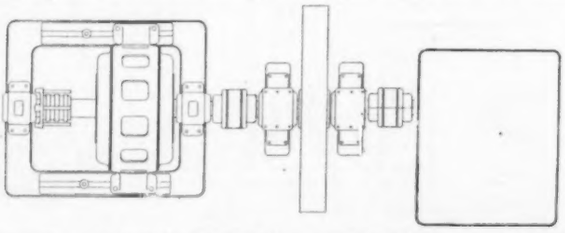


FIG. 48—ALTERNATING CURRENT MOTOR WITH COUPLED HIGHER SPEED FLYWHEEL AND KENNEDY PINION HOUSING.

ten per cent of present day practice and, while some existing tonnage mills require larger horsepower ratings, there are other mills successfully operating with smaller motors. The values given for the fly-wheel effect required for a specific mill represent good average values, although the variations found in practice are even greater than in the size of motor used.

TABLE 6

AVERAGE HORSEPOWER RATINGS, SPEEDS AND FLYWHEEL HORSEPOWER SECONDS FOR THREE HIGH PLATE MILL DRIVES.

Mill Width	Monthly Tonnage	H.P.50°C.	Roll Speed	Pinion* Speed	Fly-wheel H.P. Sec.
72 in.	8,000	1500	60	90	28,000
84 in.	9,500	2000	56	84	32,000
90 in.	10,000	2500	52	78	35,000
110 in.	12,200	4000	51	76	44,000
128 in.	14,500	5000	48	72	52,000
132 in.	15,000	5500	48	72	56,000
140 in.	16,000	6000	47	70	60,000
152 in.	17,500	6800	45	68	68,000
156 in.		7000	45	68	70,000

*Pinion speed has been taken as one and one-half times the roll speed which is within about ten per cent of actual ratio.

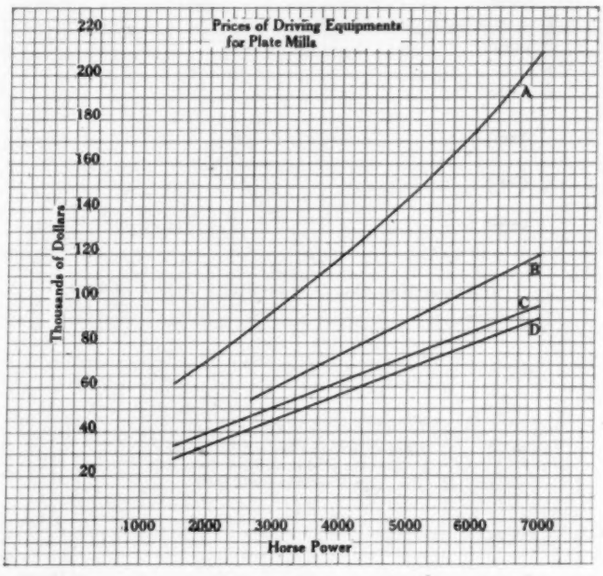


FIG. 49—PRICE CURVES FOR ELECTRICALLY DRIVEN CONSTANT SPEED PLATE MILL DRIVING EQUIPMENTS WITH FLYWHEELS.

The prices for these combinations include wound rotor induction motor with suitable control, the flexible coupling to the motor and a flywheel, but they do not include the mill coupling on the low speed side because the costs of such couplings vary with customers' requirements and have no effect on the relative cost for different motor speeds.

Curve A shows prices of direct-connected wound rotor induction motor with suitable control, flexible coupling and a separate fly wheel as shown in Fig. 45. For horsepower ratings and mill speeds see Table 6.

Curve B shows prices of wound rotor induction motor with suitable control, flexible coupling and 3 to 1 ratio gear unit having balanced flywheels on the pinion shaft as shown in Fig. 47.

Curve C gives same data as Curve B except for 5 to 1 ratio gear unit.

Curve D gives same data as Curve B except for 7 to 1 ratio gear unit.

Prices

Fig. 49 illustrates average price values for constant speed Plate Mill driving equipments for the horsepower

ratings, mill speeds, and flywheel effects, given in Table 6. The prices include a 60 cycle 2200 volt, 50°C. rating standard design wound rotor induction motor with suitable control, the flexible coupling for the motor, the flywheel, and a herringbone gear unit for the geared drives, but do not include the mill coupling because the cost of that item varies with the mill requirements and has no effect on the relative costs for the different motor speeds.

It is noticeable that for three high plate mill drives a low speed direct-connected motor with a separate flywheel is considerably more expensive than a geared drive having the flywheels on the gear unit pinion shaft. While it is true that the higher the motor speed—within practical limits—the lower the initial cost, yet it can be seen that the gain is comparatively small beyond moderate motor speeds.

When low motor speed is considered, the difficulty of mounting a flywheel of sufficient size on a gear unit of small size makes such a combination unnecessarily expensive, if not even impractical.

Fig. 50 illustrates the average price values covering the same ratings as given in Fig. 49 except that the flywheels are not included. This applies to plate mill drives where a suitable flywheel is available and only the replacement of the engine by electric drive is desired. Ordinarily, where a new flywheel is required and good engineering practice will permit, a geared unit,

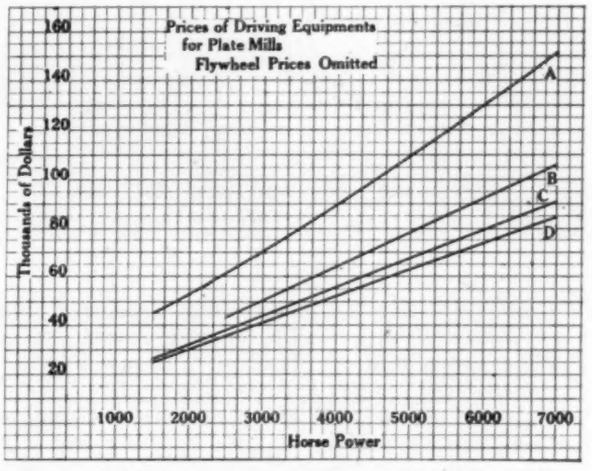


FIG. 50—PRICE CURVES FOR ELECTRICALLY DRIVEN CONSTANT SPEED PLATE MILL DRIVING EQUIPMENTS WITHOUT FLYWHEEL.

These prices cover the same equipment as shown in Fig. 49 except that the flywheel prices have been omitted.

with balanced flywheels on the gear pinion shaft is less expensive to install than a separate flywheel, either at motor or mill speed.

For plate and other similar mills where flywheels are not considered, the dimensions and cost of the gear unit is not affected to any great extent by the gear ratio within the limits of practical motor speeds. The gear units are only a little less expensive because, for good practice, it is not desirable to reduce the size of the rear unit to any appreciable extent when no flywheels are required. The reason for this is that the strength of well designed herringbone gears must always be greatly in excess of what is needed to carry the peak load on the mill. It makes no material difference, therefore, whether the flywheels are placed in front of the gears or on them, or behind them.

It should be noted that the foregoing applies to plate mills, and other mills of similar type, only.

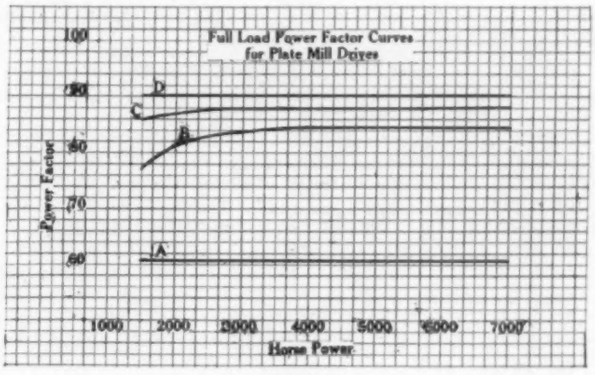


FIG. 51

Curve A shows average full load power factor values for direct-connected wound rotor induction motors for horsepowers and speeds given in Table 6.

Curve B shows average full load power factor values for motor speeds three times the mill speeds.

Curve C shows average full load power factor values for motor speeds five times the mill speeds.

Curve D shows average full load power factor values for motor speeds seven times the mill speeds.

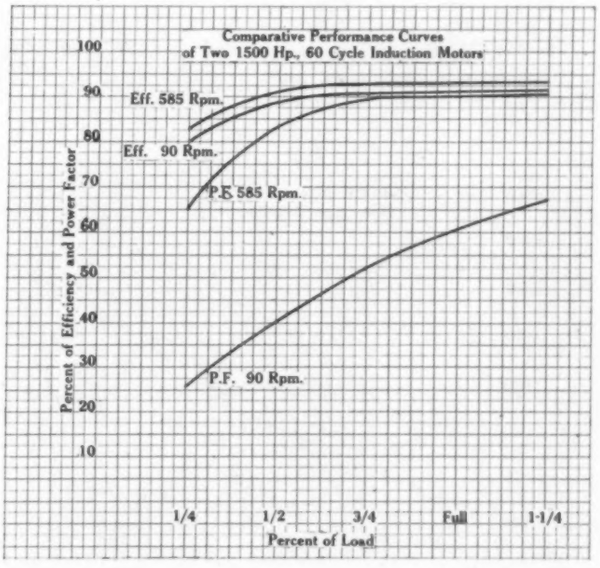


FIG. 52

One with 78 poles to give 90 R.P.M. for direct connection and the other with 12 poles to give 585 R.P.M. for use with a gear unit.

Efficiency

As previously stated, the efficiency of the direct-connected motor generally is lower than that of the higher speed machine, but, due to the losses in the reduction gears, the combined efficiency of the geared motor with its gear is usually within one per cent of the direct-connected motor. Therefore, as a whole, the

question of efficiency is not a deciding factor in the selection of either type of drive.

Power Factor

Fig. 51 illustrates average full load power factor values of 60 cycle wound rotor induction motors designed for plate mill service for the horsepower ratings and speeds given in Table 6.

It will be seen that, while larger motors of a given speed usually have a higher power factor than smaller motors of the same speed, Curve A shows the same value for the complete horsepower range. This is because plate mill speeds go down as the required horsepower goes up. It is noticeable that while the full load power factor of a direct connected motor for plate mill drive is quite low, for a moderate speed geared motor it is high, and improves slightly as the motor speed increases.

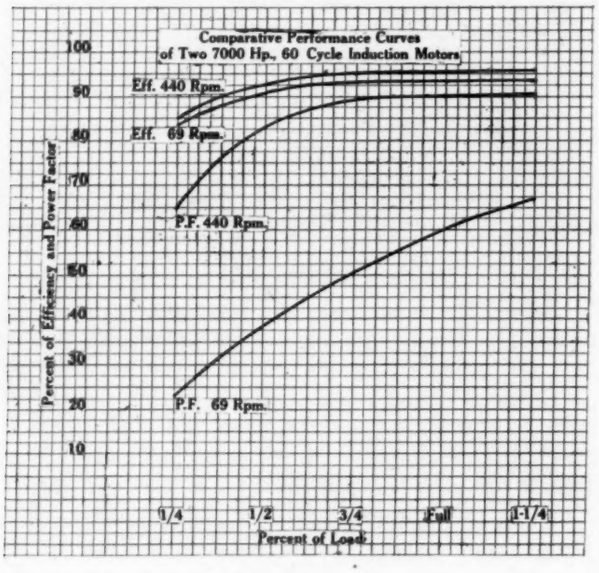


FIG. 53

One with 102 poles to give 69 R.P.M. for direct connection and the other with 16 poles to give 440 R. P.M. for use with a gear unit.

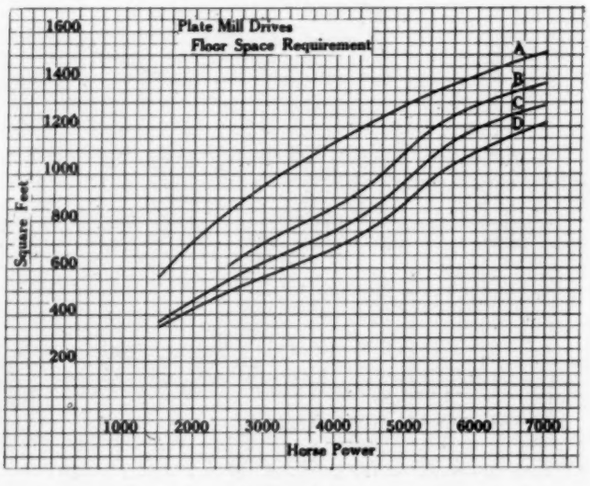


FIG. 54

Curve A shows approximate floor space requirements for direct connected units as shown in Fig. 45.

Curve B shows same data for 3 to 1 geared units as shown in Fig. 47.

Curve C shows same as B, except for 5 to 1 gear ratio.

Curve D shows same as B except for 7 to 1 gear ratio.

Performance

As it is not practical to show performance curves for all the horsepower and speed ratings illustrated in Fig. 51, the 1500 and 7000 horsepower ratings were selected as being representative of the whole. In Figs. 52 and 53 comparative efficiency and power factor values, from no load to full load, and for both low and high speeds, are given for these two sizes. The curves show that the efficiency varies little with the load or with the speed. The power factor, however, varies over a wide range. The low speed motor not only has a considerably lower power factor at full load, but it drops off rapidly as the load decreases, so that during periods of light load, and between passes when the motor is carrying only the friction load of the mill, the power factor is low.

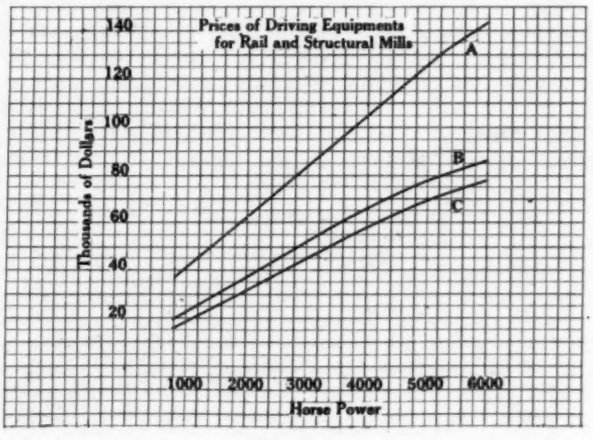


FIG. 55

Curve A shows prices of direct connected wound rotor induction motor with suitable control, flexible coupling and a separate flywheel as shown in Fig. 45. For horsepower ratings and mill speeds, see Table 7.

Curve B shows prices of wound rotor induction motor with suitable control, flexible coupling and a 3 to 1 ratio gear unit having balanced flywheels on the pinion shaft as shown in Fig. 47.

Curve C gives same data as Curve B, except for 5 to 1 ratio gear unit.

Floor Space Requirements

Fig. 54 illustrates the average space requirements, in square feet, for constant speed plate mill driving equipments, with flywheels, for the horsepower ratings, mill speeds, and flywheel effects, given in Table 6. These are only approximate values, intended for purposes of comparison, yet they show clearly that geared plate mill driving units require less floor space than direct connected units of the same horsepower capacity.

STRUCTURAL AND RAIL MILLS

Many structural and rail mills are driven by adjustable speed motors. For the sake of comparison,

however, only constant speed wound rotor induction motors are being considered in Table 7, which gives average horsepower, speed and flywheel effect values for the different sizes of mills in common use.

TABLE 7

AVERAGE HORSEPOWER RATINGS, SPEEDS AND FLYWHEEL HORSEPOWER SECONDS FOR CONSTANT SPEED STRUCTURAL AND RAIL MILL DRIVES

Size Mill	Horsepower 50°C.	Mill Speed	Flywheel H.P. Seconds
12	800	125	10,000
16	1,200	110	14,000
18	1,800	100	21,000
22	2,500	90	30,000
24	3,000	85	34,000
26	3,200	80	37,000
28	5,000	85	45,000
28-32	6,000	97	47,500

Because of the similarity in three high plate mill and constant speed structural and rail mill drives, no further comments are necessary.

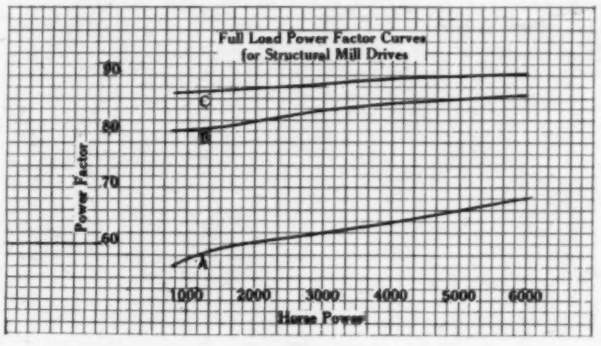


FIG. 56

Curve A shows average full load power factor values for direct connected wound rotor induction motors for horsepower ratings and speeds given in Table 7.

Curve B shows average full load power factor values for motor speeds three times the mill speeds.

Curve C shows average full load power factor values for motor speeds five times the mill speeds.

PRICES

Average price values for constant speed structural and rail mill driving equipments for the horsepower ratings, mill speeds and flywheel effects shown in Table 7, are given in Fig. 55. These are average values intended for purposes of comparison only. They include a 60 cycle, 2200 volt, 50°C. rating, standard design, wound rotor induction motor with suitable control, the flexible coupling for the motor, the flywheel and the herringbone gear unit for the geared drives, but they do not include the mill coupling.

Price comparisons for direct connected and geared structural and rail mill driving equipments are so similar to the plate mill drives discussed previously that no further comments are required.

As the performance curves of wound rotor induction motors for structural and rail mill drives are similar to those shown for the plate mills, only the relative power factor values need be considered.

Power Factor

Fig. 56 illustrates average full load power factor values for 60 cycle wound rotor induction motors designed for structural and rail mill service for the horsepower ratings and corresponding speeds given in Table

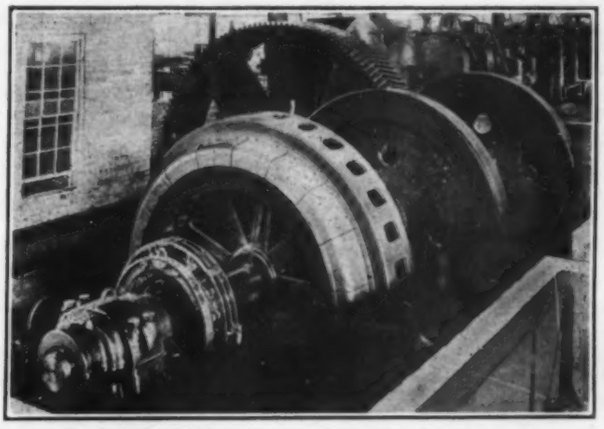


FIG. 57—1,500 HORSEPOWER, 270 R.P.M., WOUND ROTOR INDUCTION MOTOR GEARED UNIT DRIVING SHEET MILL AT THE YOUNGSTOWN SHEET & TUBE COMPANY'S PLANT, WARREN, OHIO.

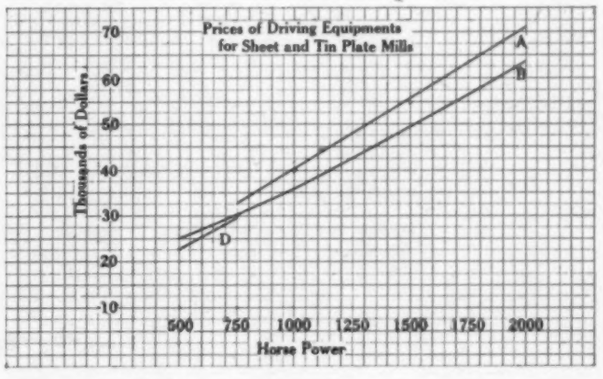


FIG. 58

Curve A shows prices of 234 R.P.M., wound rotor induction motor with control, gear unit having balanced flywheels on the pinion shaft, flange coupling, extension shaft and outboard bearing.

Curve B shows prices of similar equipments for 294 R.P.M. motor driving units.

Curve D shows similar data for 440 R.P.M. motor driving units.

For 500 horsepower drives, extension shaft and outboard bearing has been omitted as these small drives are always placed on one side.

For 352 R.P.M. motor driving units prices are not given as they seem to vary greatly with different gear manufacturers.

7. As on plate mill drives, the power factor of the direct-connected equipment is considerably lower than that of the geared equipments. It is noticeable, however, that the power factor increases for the higher horsepowers.

Floor Space Requirements

The average space requirements for standard and rail mill drives are so similar to the ones shown for the plate mill drives that no further discussion is deemed necessary.

SHEET AND TIN PLATE MILLS

Sheet and tin plate mills run at such low speeds that it is practically impossible to obtain adequate flywheel effect with wheels running at mill speed. The most common sheet mill installations consist of a wound rotor induction motor and herringbone gear unit with balanced flywheels on the pinion shaft, as shown in Fig. 57.

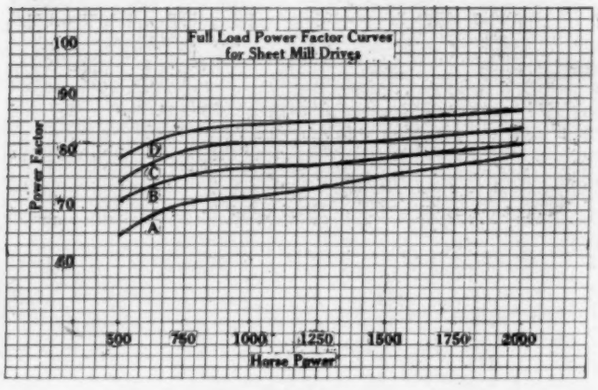


FIG. 59

Curve A shows average full load power factor values for 234 R.P.M. wound rotor induction motors.

Curve B shows similar data for 294 R.P.M. motors.

Curve C shows similar data for 352 R.P.M. motors.

Curve D shows similar data for 440 R.P.M. motors.

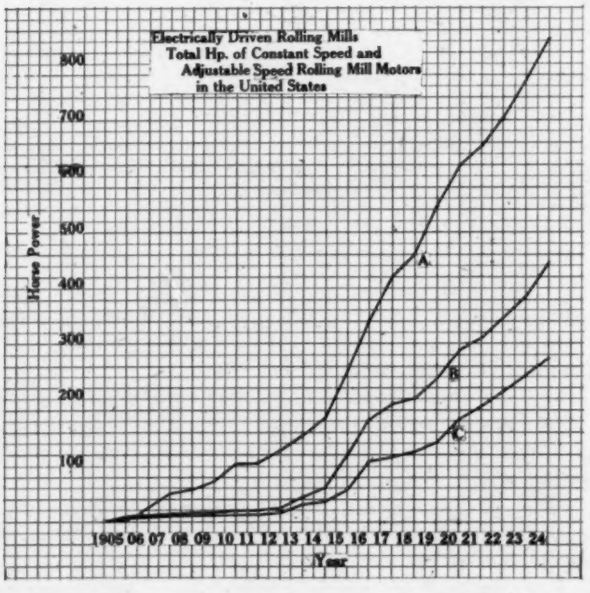


FIG. 60

Curve A gives total horsepower of constant speed main roll drives.

Curve B gives total horsepower of adjustable speed main roll drives including reversing motors.

Curve C gives total horsepower of adjustable speed main roll drives, reversing motors not included.

Table 8 gives horsepower ratings and recommended flywheel horsepower seconds for sheet mill drives operating at thirty revolutions, which is a good average mill speed.

TABLE 8

AVERAGE HORSEPOWER RATINGS AND FLYWHEEL SECONDS FOR SHEET AND TIN-PLATE MILL DRIVES

Finishing Stands	Horsepower 50°C.	Flywheel H.P. Seconds
2	500	12,500
2	750	18,000
4	1,000	23,000
4	1,250	27,000
6	1,500	30,000
6	1,750	33,000
8	2,000	35,000

Figure 58 illustrates average price values for sheet and tin plate driving equipments for the horsepower ratings and flywheel effects given in Table 8. These are average values intended for purposes of comparison only. The prices include a 60 cycle, 2200 volt, 50°C.

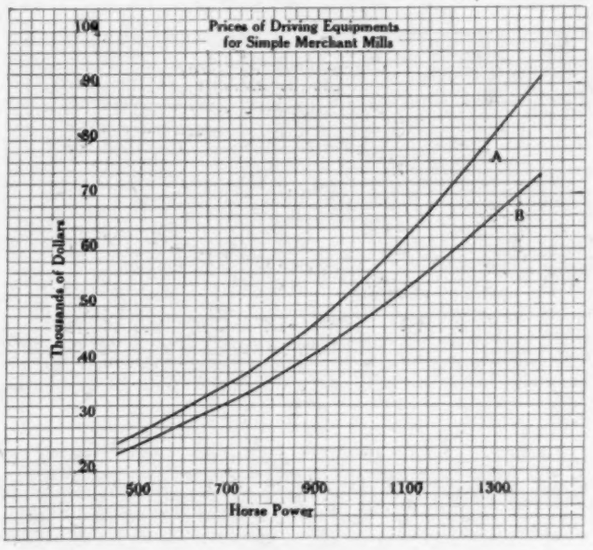


FIG. 61

Curve A shows prices of a direct current adjustable speed motor with suitable control, synchronous converter, transformer, and switchboard, flexible coupling for the motor, and flywheel.

Curve B shows similar price data for 3 to 1 ratio geared driving unit.

rating, standard design, wound rotor induction motor with suitable control, the gear unit, the flywheel, the extension shaft, the outboard bearing and the flexible coupling to the motor, but do not include the mill couplings.

Sheet and tin plate mills run at such low speeds that large gear ratios become necessary in order to obtain good motor performance.

A gear ratio of 8 to 1 is quite common and 10 to 1 is often used. Although the tendency is toward higher gear ratios, yet it is unusual to find sheet mill installations where it is materially in excess of 12 to 1, for single reduction, except in sizes less than 1,000 h.p. where a ratio of 14 to 1 comes within the limits of practical gear design for a single reduction.

Power Factor

Fig. 59 shows average full load power factor values of 60 cycle wound rotor induction motors designed for sheet and tin plate mill service for the horsepower ratings and mill speeds given in Table 8. It is noticeable that, because of the relatively low horsepower requirements, a fairly high speed motor is desirable to obtain a good power factor.

Floor Space Requirements

Since all present day sheet and tin plate mill drives are geared units it naturally follows that higher the motor speed the less the required floor space. Variations in different gear manufacturers' dimensions make it impossible to show any composite floor space curves.

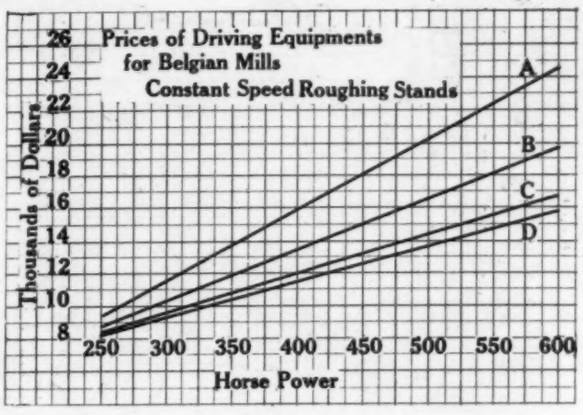


FIG. 62

Curve A shows prices of wound rotor induction motor with control, coupling, and 3 to 1 ratio geared unit having flywheels on the pinion shaft.

Curve B gives similar data for 5 to 1 ratio geared unit.

Curve C gives similar data for 7 to 1 ratio geared unit.

Curve D gives simliar data for 9 to 1 ratio geared unit.

MERCHANT MILLS

The various comparisons that have been made so far in this paper have dealt with constant speed wound rotor induction motors, due to the fact that they are more commonly used on main roll drives, as shown in Fig. 60. In order to extend our comparisons to adjustable speed equipments, merchant mill drives may be considered as a typical example.

As a rule, the speed range required on a Merchant mill is one in which the minimum speed is approximately 60 per cent of the maximum speed, although a speed range of 2 to 1 is not uncommon.

SIMPLE MERCHANT MILLS

Table 9 gives the horsepower, speed range and flywheel effect for simple Merchant mills which represent good average values and will serve well for purposes of comparison.

Prices

Fig. 61 illustrates average price values for adjustable speed, simple Merchant mill driving equipments for the ratings given in Table 9. The prices include a direct current adjustable speed motor with suitable control, the synchronous converter, transformer and switchboard, the flexible coupling for the motor, the flywheel and a gear unit for the geared drives.

TABLE 9

AVERAGE HORSEPOWER, SPEED RANGE AND FLYWHEEL HORSEPOWER SECONDS FOR SIMPLE MERCHANT MILLS

Mill Dia.	Aver. Billet	Aver. Tons Per Month	H.P.	Speeds From R.P.M.	Speeds To R.P.M.	Flywheel H.P.Sec. Low Speed
8	1¼	1,200	450	240	355	2,850
9	1¼	1,500	500	200	300	3,200
10	4	2,000	600	175	260	3,550
12	4	2,500	750	135	200	3,200
14	4	3,000	900	105	160	5,200
16	6	4,000	1,100	75	125	5,650
18	6	5,000	1,400	60	100	7,300

For the sake of simplicity, these prices are based on direct current motors. Alternating current adjustable speed set prices would be lower for some ratings and higher for others.

As only 3 to 1 gear ratio is shown, it should be noted that where motor design permits the use of a higher speed motor a lower initial cost is to be expected.

BELGIAN MILLS

Table 10 gives horsepower, speed range and flywheel effect for Belgian mill roughing stand drives, and Table 11 gives similar data for Belgian mill finishing train drives.

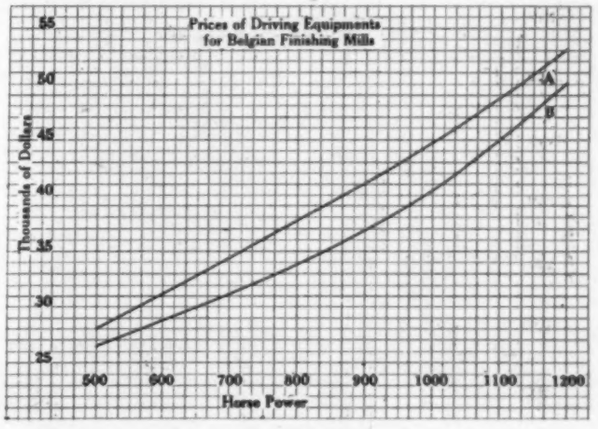


FIG. 63

Curve A shows prices of direct current adjustable speed motor with suitable control, synchronous converter, transformer and switchboard, flexible coupling for the motor and a flywheel.

Curve B shows similar data for 3 to 1 ratio geared driving unit.

TABLE 10

AVERAGE HORSEPOWER, SPEED AND FLYWHEEL HORSEPOWER SECONDS FOR BELGIAN MILL ROUGHING STANDS

Mill Dia.	Aver. Billets	Aver. tons per month	H.P. 50°C.	Constant Speed R.P.M.	Adj.Speed From R.P.M.	Adj.Speed To R.P.M.	Flywheel H.P.Sec.
12″	4″	1,500	250	145	120	175	3,750
14″	4″	2,000	350	125	100	150	5,250
16″	6″	2,500	400	100	75	125	6,000
16″	6″	3,500	450	100	75	105	6,700
18″	8″	4,500	600	80	60	100	9,000

TABLE 11

AVERAGE HORSEPOWER, SPEED AND FLYWHEEL HORSEPOWER SECONDS FOR BELGIAN MILL FINISHING STANDS

Mill Dia.	H.P. 50°	Speed From	Speed To	H.P.Sec. Low Speed
8″	500	275	500	2,200
9″	650	235	425	2,900
10″	750	200	350	3,300
12″	1,000	150	260	4,400
14	1,200	120	200	5,250

Prices

Fig. 62 illustrates average price values for constant speed Belgian mill roughing stand driving equipments for the ratings given in Table 10.

Fig. 63 shows similar price data for adjustable speed Belgian mill finishing train driving equipments for the ratings given in Table 11.

It will be noted that for the horsepowers and speeds represented the direct connected adjustable speed equipments are more expensive than geared units. It is not to be taken for granted that in all cases direct connected Merchant mill drives are more expensive for there are conditions where the reverse is true.

Performance

The performance of an alternating current adjustable speed equipment depends largely upon whether a high speed motor, with a gear unit or a low speed direct-connected motor is used. The performance of a direct current adjustable speed equipment is relatively independent of the type of drive used.

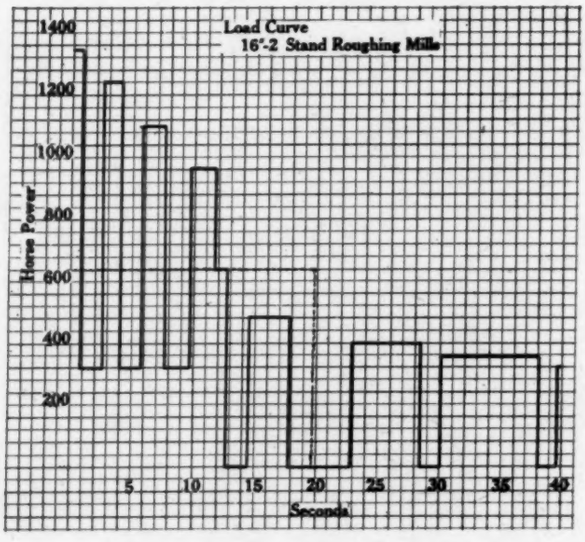


FIG. 64

Due to the many different factors involved, it does not seem practicable to show detailed power factor and efficiency curves of the various adjustable speed drives.

DETERMINATION OF HORSEPOWER REQUIREMENTS

In determining the horsepower required to drive a Merchant mill, the question of proper flywheel effect plays an important part. As there is no type of mill where a greater difference of opinion exists regarding horsepower, it might be interesting to study the load requirements on a typical Belgian mill showing how a properly selected flywheel affects the application of suitable driving equipment.

In figuring a mill application it is usually necessary to go through a number of calculations, in order to determine the most economical relation between motor capacity and flywheel effect, and the best location for the flywheel.

The solid lines in Figs. 64 and 65 represent respectively, the loads on a 16 in. two stand rougher and a 12 in. five stand finishing train, when rolling 4x4 in. billets to ¼ in. rounds. Each load diagram covers one cycle, a piece being entered in the mill every 40 seconds.

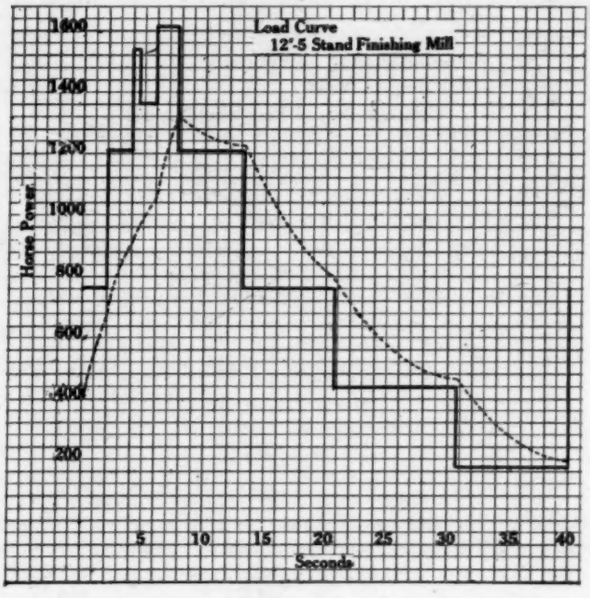


FIG. 65

The average load on the rougher is 378 h.p. with peaks of 1390 h.p. A motor, however, cannot be applied on the basis of the average horsepower on a load of this kind. The heat generated in the motor is proportional to the square of the load, hence the heating effect of a cycle is proportional to the square root of the average squares or the root mean square. The R.M.S. value of this cycle is 550 h.p.

A 600 h.p motor would be of the proper size to carry this load from a heating standpoint. However, the peaks are so high during the first few passes that undue strains would be placed on a machine of this capacity. A 900 h.p. motor would be of more nearly correct size for this load, as the motor would then be subjected only to 55 per cent overload on each cycle.

This, however, would not make a very desirable installation for several reasons. Both the electrical equipment and the power line would be required to carry sharp peak loads, rising from minimum to maximum value almost instantaneously. Due to some factors, which have not been taken into consideration, such as cold steel, these loads would occasionally run much higher than calculated. In fact, these unforseen conditions would probably at times cause a shut-down of the mill. Besides this, the continuous carrying capacity of the motor would be almost twice as great as required by the R.M.S. load.

With the proper flywheel effect, and means of utilizing it, the continuous rating of the motor can be reduced to 500 h.p. This is 50 h.p. less than the calculated R.M.S. value of the cycle, but when the peaks are kept from the motor, the new R. M. S. load will be well below the motor rating.

Due to the fact that the steel is looped throughout the finishing train, the load on this drive, as shown in Fig. 65, builds up to a high value during the first part of the cycle and then falls off gradually. A 1000 h.p. motor would be of sufficient continuous capacity to roll this schedule, but it would be subjected to a peak rising to a maximum value of 162 per cent every 40 seconds under normal operation. Unforseen conditions could easily increase these peaks beyond the overload capacity of the motor.

A flywheel of the proper characteristics, and means of utilizing it, will bring this peak down to a more reasonable value.

It is said that successful engineering consists largely of doing—a little better—what some other engineer has already done. In other words, before undertaking any job, it is desirable to become thoroughly familiar with the best work already accomplished in that particular field. It is hoped the information given in this paper will serve as a convenient reference in analyzing the different factors involved in the selection of direct-connected and geared main roll drives.

DISCUSSION

Barton R. Shover*: The Association is to be congratulated upon having presented to them the best collection of data and general information in regard to motor drive of rolling mills, that I have ever seen in any one article on that subject.

One of the writer's remarks deserves emphasis. He states that while general information is sufficient as a basis for estimates, each actual installation should be given careful consideration because of the many governing factors. More instances where an installation has failed to give the results expected are due to copying what someone else has done, than to any other cause. It is seldom that all factors are the same in any two installations; therefore, the wise executive will have each case calculated separately.

Something has been said about utilizing existing engine fly wheels. They may answer in some cases, but engine flywheels were designed to correct the inherent variation in angular velocity of the shaft, and not to in any way equalize the driven load. In one instance, the flywheel effect of the engine replaced was just one-seventh that which was installed with the motor and gear drive.

Again the Electrical Engineers owe a vote of thanks to their mechanical brothers for another nail in the coffin of the steam engine drive, due to designing reliable gear reduction units.

The paper just read shows the advantage of 60 over 25-cycle apparatus, and pioneers in the electrification of rolling mills have frequently been blamed for introducing the lower frequency. The decision in favor of 25 cycles was correct when it was made, but changed conditions would secure a reversal of this decision were it to be made today. When mill electrification started the gas engine was supposed to be the last word in prime movers, and successful parallel operation seemed to demand low frequency. Niagara Falls had adapted 25 cycles, and the consensus of opinion favored that frequency for power work. Central stations fought shy of loads such as rolling mills offered, even if their rates had not been prohibitive. There were no reliable gear reducing units of large sizes available, so the cost and operating characteristics made the choice of 25 cycles almost imperative. Looking back in the light of present knowledge, 60 cycles could have been adopted, consequently should be used in new installations whenever practicable.

The comparison between 25 and 60 cycle equipment formed part of an investigation which I now have on hand. The basis of this estimate was average figures, which are interesting.

The efficiencies of about 100 motors as nearly as possible of the same rating and speed, were averaged for each frequency, the average being almost identical for both frequencies. Speed of motors of equal capacity apparently has little effect upon the efficiency. Similar figures for transformers and motor-generators, however, showed better efficiency for the higher frequency.

The greatest difference, however, is in the cost. Figures on duplicate equipment of different size units of each class were obtained from various manufacturers, the average being as follows:

Cost per K.W. of Rated Capacity

	25 Cycle	60 Cycle
Turbo-generators	$19.33	$17.00
Motor-generators	19.60	18.35
Transformers	2.47	1.56
High voltage motors for mill drive.	13.49	10.62

The above prices are for electrical machinery only and do not include such items as foundations, installation, condensers, etc., which would be the same for both frequencies.

No figures were made in regard to low voltage auxiliary motors, the cost of which is considerably in favor of 60 cycles.

The question of connecting the electric systems of Steel Works with those of the Utility Companies has, of late, assumed considerable importance, and in such cases the cost and losses of frequency changes plays no small part.

The paper just presented contained curves showing the results obtained from two different kinds of secondary control on the same mill motor. Curves of this character are apt to be misleading unless all conditions are stated. In the case cited, the curves are undoubtedly correct, and show which control is most desirable for this particular case, but it must not be forgotten that, in most cases, it is possible to so change conditions that the curves shown could be practically reversed, but at the expense of efficiency and average speeds. Each of these types of control has its advantages and each its disadvantages, and both advantages and disadvantages should be carefully considered before making a choice for any particular installation.

Frank E. Leahy*: I enjoyed the paper very much. It certainly covers the subject and gives us

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some data for estimating purposes that will be of value to all of us. The point that was brought out clearly in the paper was the number of elements that enter into the analysis of a rolling mill drive. At the present time we have up the question of changes to be made on a number of mills, and some of the points that were mentioned this afternoon have been up for discussion. One of the points is power factor. We are using certain types of motors, and the question of power factor correction has come up very frequently; also flywheel effect and how to control it. While these were mentioned in Mr. Hurme's paper, I presume the scope of the paper did not permit going into detail, but if there are any other speakers here who have had experience on power factor and flywheel control, I would be very glad to hear it.

R. H. Keil*: I would like to ask Mr. Shover a question in connection with the figures which he has given comparing the cost of 60 and 25-cycle mill electrical equipment. The point which I would like to have brought out is whether these figures insofar as they apply to mill drives, included reduction gears with the 60-cycle motors, or whether the comparison was based on the same motor speeds throughout.

B. R. Shover: As the comparative figures given on those motors were on as near as possible the same speeds and horse power, gear drive was not included, as the gear would have cost the same in both cases.

G. E. Stoltz†: Mr. Hurme has shown curves on two plate mills, one with the liquid slip regulator type of control and the other with the notching-in relay magnetic type. Mr. Shover indicates that the results obtained could be reversed, but I believe this would be rather difficult and under every-day operating conditions, the liquid regulator would show better results than could be obtained from any other type of control.

Mr. Leahy has introduced the question of plant power factor. Power factor is of considerable importance to those who purchase power, particularly when it is 60 cycle. This problem is not often as important in a 25-cycle plant. There are, of course, small plants where a large number of small induction motors are used where it is possible to get an overall power factor of 50 to 60%. This, of course, is undesirable under any condition, but in our large steel mills the power factor usually is around 80 to 90%, and where 80% power factor generators are installed, there is not so much to be gained in correcting this power factor. However, where power is purchased and a rebate is given for power factor correction, a definite net return can be obtained by approaching 100% power factor.

Power factor correction can be obtained on synchronous converting apparatus and on synchronous motors driving compressors, fans, etc. There are some installations of synchronous motors on mills which may be satisfactory, but there are number of types of mills where operating results would be compromised by the installation of a synchronous motor. When the electrification of a mill is considered, I believe it would be best to apply apparatus, that is motor, control, couplings, and gear unit and flywheel where they are required, which are inherently best adapted to give ideal mill operating results. We must realize that the men operating the mill do not appreciate the characteristics or limitations of the driving apparatus, and while we may install something that can be proven theoretically to be adequate, it may be impractical. By keeping in mind the actual mill requirements and applying apparatus, the characteristics of which obtain the greatest ease in performing the work required, such matters of power factor correction can then be taken care of in other equipment.

There is no question but what the gear manufacturers have promoted electrification of mills, but, of course, the application of a geared motor is not to be recommended unless the initial cost of the installation is sufficiently less than that of the direct connected motor, to warrant its installation. Better power factor is obtained on a geared A.C. motor, but the preference for a direct-connected machine is usually great enough to warrant its selection, unless the first cost of the geared drive is sufficiently less to offset this. Gearing is not so common on direct-current motors. On this class of machines we have the commutator to contend with and the advantage of having low commutator speeds is a very important factor to be considered. If a direct-current motor is to be geared to the mill, it is highly important to have a quiet running gear with a flexible coupling that will not transmit vibration from the gear to the commutator.

James Farrington*: I might say a few words on one or two questions that were asked. First in regard to the regulator. We have both types and we find we can get closer regulation with the liquid regulator, that is, if conditions change in the mill, we find we can keep nearer ideal conditions with liquid regulator than with magnetic contactor.

Whether 25 or 60-cycle should be installed. We started with 25-cycle and about 6 or 7 years ago changed over to 60-cycle. There has been nothing done with 25-cycle that we could not do economically with 60, and we are gradually replacing 25 with 60-cycle equipment.

In regard to couplings, flywheels and gears. Mr. Hurme brought out ideal conditions in each one, but we who have to tie these three units together are the ones who get the bumps. In talking to a representative of a coupling manufacturer about sheet mill drive, he attributed our coupling trouble to the fact that the gear manufacturer was wrong in putting his gear upside down. I asked him what he meant, and he said our unit was so constructed that load on the mill tends to raise flywheel shaft in its bearings. We said we understood that was the ideal condition, that the gear manufacturer said that was the only correct way, so I put it up to the gear unit manufacturer this evening and he says it is the ideal way. So I trust this representative of a coupling manufacturer will bring up that question and get it answered by the gear unit manufacurer. The coupling representative also asked if we had end-play in the armature. I said, surely, we always have. He said he asked the manufacturer and he replied that there was

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no change from no load to full load. I said I understood differently. I would like to ask Mr. Hurme to enlighten us on this subject.. The question was brought out as to whether there should be any end-play in herringbone gears. Some manufacturers say to anchor the gear and let the flywheel and pinion take up any of the oscillations, that the coupling should be so designed as not to transmit that oscillation back tc the motor. In our case it is transmitted back to the motor. We would like to know whether we should have end-play, or whether attachment should be made to remove the end-play altogether, as this end play is giving us considerable trouble? I would like to ask if there are couplings made which the manufacturers guarantee will transmit their rated load within the limits of misalignment without injurous end thrust on armature bearings and coupling?

P. C. Day*: I must first apologize to Mr. Hurme. He sent me an advanced copy of his paper with an invitation to write some discussion. That advanced copy arrived in Milwaukee on Wednesday last. I was not there and did not return until Friday morning, and I did not have the time to write anything. However, there isn't much left to say. I would like to contribute my small voice in gratitude to Mr. Hurme for his wonderful paper. A few good diagrams and curves, and the very interesting information he gave us, really give no idea of the amount of work it takes to prepare such a paper. I have tried to do it myself sometimes and know what it means. We can all feel very grateful to him. I regard this paper as a non-controversial, valuable contribution to the subject of electrically driven mills. There isn't much I would wish to say in criticism of such a paper. I do not think this is the occasion for controversy; the paper is statistical but not controversial. Those of us who make gears know there are times and seasons when we can talk about them. Falk gears are fairly well known in this country and some of the examples that were shown to you on lantern slides were pictures of Falk products. Regarding the illustration of a high speed rail mill drive, I think Mr. Hurme must have obtained that picture from the Allis-Chalmers Company, and thereby hangs a little tale. The Allis-Chalmers Company are close friends and neighbors of the Falk Corporation, and in this particular case, we made the gear and they made the motor. The Allis-Chalmers Company obtained permission to photograph the entire installation, and having a proper regard for the fact that they were the Allis-Chalmers' advertisers, not the Falk Company's, they carefully removed the Falk Company's name from the retouched picture. We have been razzing them about it ever since!

Mr. Hurme touched mainly on the subject of cost, efficiency and power factor in relation to direct and geared drives, with certain differences in favor of higher speed motors. There was one point he did not mention, viz., that with higher speed motors it is easier to obtain the flywheel energy you wish to get. In general, if any criticism can be allowed, Mr. Hurme's figures for flywheel energy on different rail mill and plate mill drives are rather below what we should recommend, and from the point of view that a few thousand horse-power seconds costs so little when connected to a high speed motor, that is to say with the flywheel revolving at high speed, it is often worth while to give more energy to the flywheels when, by doing so, you maintain a better average of speed in your mill and, at the end of the day or week, a greater production.. Increased production is what everybody is aiming at. As near as I can remember, the horse-power seconds in that Ensley rail mill were about 90,000. The mill began to make records of production from the day the motor was started up, the difference being due to better maintained speed. The old mill had an engine with flywheel and when the load came on it slowed down and did not produce as much as with well maintained speed. I believe the tendency in the future will be to make greater and greater use of the kinetic energy of flywheels, not only for single mill drives, but mills of the continuous and semi-continuous type, and instead of driving by groups from a single large motor, connected through a line shaft and a large number of bevel gears, I expect to see, in the not very distant future, those groups broken up with smaller, high speed motors, and high speed flywheels right down the line. Some installations of this kind have been made, notably at the American Rolling Mill plant at Ashland. I have seen that mill operating, but what I know about it is more or less confidential, and unless the American Rolling Mill people would care to discuss it, I wouldn't like to say anything at this meeting.

J. D. Wright*: I am sorry that after receiving an advance copy of today's paper, I did not have sufficient time to prepare the kind of discussion which is called for by Mr. Hurme's excellent contribution to the records of our society. It is very evident that a great deal of time and effort has been spent in compiling the data which has been included, and Mr. Hurme is to be congratulated on the results of his work.

With the increasing use of 60-cycles the manufacturers of herringbone gear units have contributed largely to the economical application of rolling mill motors. A large slow speed 60-cycle machine is, for reasons which Mr. Hurme has pointed out, inherently an expensive machine, with power factor characteristics undesirable to say the least. The uneconomical installation of such motors has been rendered unnecessary by reliable gear units.

Many of the large steel plants in this country have used and will continue to use 25-cycle power. With this frequency the undesirable characteristics of slow-speed 60-cycle motors are largely eliminated. I would, therefore, caution you not to draw too general conclusions from Mr. Hurme's paper, as he has confined his comparison between slow speed and high speed machines almost entirely to 60-cycle designs. Under the subject of maintenance it was pointed out that slow-speed direct-connected motors require a relatively large number of coils, and therefore the chance of insulation failure would be much greater than with high-speed machines. Such might seem to be the case, but experience has shown that it is from the slow-speed machine that we get the most reliable and unfailing service.

Where flywheels must be used the present-day practice on geared drives of mounting two flywheels on the pinion shaft has many advantages and is largely to be recommended With direct-connected motors, I, personally, would recommend

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that the flywheel be considered entirely apart from the mechanical design of the motor. I maintain that in general, it is undesirable to incorporate the necessary flywheel effect in the motor rotor, or in a wheel mounted on the rotor shaft between the motor bearings. It will usually be found more economical to put the wheel on its own shaft carried by its own bearings.

Mr. Hurme, of course, could not pass over the subject of flywheels without touching on the control which should be provided to obtain proper utilization of the flywheel effect. I would have been greatly disappointed had he failed to again show his charts comparing slip regulator and magnetic controls. I will only say, however, that the controversy has not yet been settled, because there are excellent arguments for each type of control as well as excellent installations of each.

I am sure that Mr. Hurme did not mean to give the impression by his statement on Page 9 that frequent interruptions were experienced on the mill driven by the 4,000 H.P. motor, the input to which is shown in Fig. 18. Even with the small flywheel energy which is available from this drive, which is illustrated in Fig. 21, this 110" plate mill and another with a duplicate drive, at the Sparrows Point plant of the Bethlehem Steel Co., have established an enviable reputation for turning out tonnage.

J. J. Serrell*: As Mr. Hurme's paper and the January issue of "Iron and Steel Engineer" both show, geared motor drives may be thought of as belonging in three separate periods.

Prior to 1915 they were more or less in an experimental stage, as less than 10% of today's drives were installed up to that time. That the design and workmanship were both generally good is indicated by the fact that many of these drives are now in operation.

In the next five years (1916-1920) there was an urgent demand for increased steel production and more than 50% of the present geared motor drives were then installed.

The last four years has been a period of study and refinement both in design and in workmanship. This is true both for geared drives and for flexible couplings. The gears and the couplings now being installed are more economical and more reliable than some of the earlier ones.

The need for a flexible coupling, its size and capacity depend upon a great many things. How the gear is made is one thing. How much maximum load is to be transmitted and at what speed is another. And just as important, how the entire drive is installed and operated.

So far as flexible couplings are concerned, this and gear drives being a mechanical problem, I would like to see this a society of Electrical and Mechanical engineers, rather than, as its name indicates, one particularly for electrical engineers alone. In some mills it is unfortunately the case, that the electrical engineer takes care of the motor, the mechanical engineer takes care of the gears, and neither one takes care of the coupling.

Mr. Hurme has stated some ideal requirements for couplings. I do not think any coupling now made will meet those conditions perfectly. Any coupling that has metal to metal contact has a certain amount of internal resistance to endwise movement. Endwise motion at the coupling usually comes either from the motor or from the gears. It would be an ideal condition for the coupling if there were no endwise movement. Mr. Sykes said something tonight I am glad to hear, that a well-made herringbone reduction gear should have no endwise motion.

I would like to hear the question answered that Mr. Farrington asked: Does an A.C. motor have one electrical center when running under no load conditions, another electrical center when under peak load conditions, and perhaps another when it is reversed? To provide successful couplings it is simply a matter of getting together on such things, with the motor manufacturer and with the gear manufacturer, then make the proper design and application based on experience. We are trying to design and build flexible couplings to meet all usual operating conditions.

E. Dukes*: There has been a great deal of very well deserved tribute paid to Mr. Hurme for the splendid work he accomplished in presenting this paper, and there is nothing more I could add, and certainly I would not detract from it, so I will devote my remarks to the questions put forth by Mr. Farrington and Mr. Cummins.

In answer to the first question put forth by Mr. Farrington, should a pinion have end-wise motion, I will say that our practice is to have the pinion fixed between bearings not permitting end-wise motion, however I know of a very reputable manufacturer who builds drives allowing the pinion to float, and attaining good results. So this point is only a question of manufacturing methods.

Second question, should the tooth load on pinion be up or down? Our practice is to have the tooth load on pinion up, when the drive is equipped with two flywheels mounted on pinion shaft; if the tooth load is down it generally results in too high bearing reactions and as a general rule the factor of bearing pressure per square inch by rubbing velocity is around 100,000, resulting in heating of bearings, unless bearings are water cooled or equipped with a force feed or gravity feed lubricating system. If the flexible coupling can not take care of this condition, I believe that is the fault of the flexible coupling. In cold mill drives, where there are no flywheels, there I believe in the tooth load on pinion being down, due to the fact that it eliminates vibration from the pinion shaft as these vibrations are transmitted to the steel and cause chatter marks.

Regarding the question of Mr. Cummins, in a continuous bar mill drive should the stands be driven by a train of bevel gear drives through one motor, or should each have an individual motor drive. We don't believe in either of them. We believe in a primary herringbone gear drive connected through a universal spindle to a secondary herringbone gear drive. In the last four years we built six such installations, three for the Tennessee Coal Iron & Railroad Company; one of them is driving six stands of 16" continuous bar mills, another 4 stands of 12" continuous bar mills, and a third 2 stands of 12" mills. Lately we made one tandem mill drive for the Bethlehem Steel Company for their Sparrows Point Plant, which is laid out to

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drive three trains of cold mills, 7 mills in each train. This mill was originally laid out to be driven by a train of bevel gears, however, our proposition of a tandem gear drive was accepted and that is the way we built it.

A. C. Cummins*: Supposing the mills are 15 to 20 feet apart.

E. Dukes: Then I do not believe in bevel gear drives either. Drive each of them through a separate motor and gear drive. It gives separate control for each mill; those three motors most probably could be duplicates, and I believe the first cost and maintenance cost would be less.

J. J. Serrell: Mr. Dukes has mentioned two conditions. He spoke of one case where the pinion was lifted up to partly counteract the weight of flywheel, and he spoke of another on cold mills where the pinion was forced down. I would like to ask his opinion of the following drive: On a constant direction drive (sheet mill), but with intermittent loading, if the weight of the pinion, its shaft and flywheels is considerably less than the maximum tooth pressure of the gears, should the pinion drive down against the gear teeth so the pinion shaft will tend to peen out the top halves of its bearings, or should the pinion drive up against the gear teeth so the pinion shaft will always rest in the lower halves of its bearings?

A. J. Standing†: I cannot refrain from paying my tribute to Mr. Hurme on the value of his paper, which has given us reference data that will enable us to answer rapid-fire questions from the management as to what it will cost to put a motor on such and such a mill.

That the development of electrical drives in steel mills in the last twenty years has been along sound economical lines, is evidenced by their continued application. We also have noticed the trend from 25 to 60-cycle charactistic power being more available in quantities of interest to the steel plant and this change has paralleled the development of mill drive motors. Concurrent with these two advances we find the development of gear-drive units. These three factors converge to give us the developed drive which has become modern practice to the end that we may roll steel more economically, which is the objective of our mills. These advantages have been realized without the penalty of higher first cost, giving us not only the economy of lower first cost, but lower operating cost, and reduced floor space. It is interesting to realize the spare part possibility which this type of drive gives to plants where there are duplicate drives. It means that the carrying of spare drive units now has reached a stage where the cost of having a spare unit is no longer prohibitive. The only point that might have a bearing on this spare feature is the fact that with 60-cycle equipment, as Mr. Hurme brought out in his paper, the tendency is to increase the diameter and decrease the width and this characteristic may, in the case of large units, involve transportation difficulties.

I have a question relative to couplings: We have three dirct-connctd mills and on one we experience a certain amount of shove from the mill. If that occurs will the coupling protect the gear drive from the push of the mill? In applying flywheels to pinion shafts running at motor speed, the question of flywheel strength and speed may preclude the use of cast flywheels and may involve the use of plate flywheels. These are points I would like to have information on.

G. W. Hall*: We have had very broad and wide experiences in the lubrication of all types of gears. When liquid oil is used, sprayed on the gears, we have found that the oil passing over the sharp edges of the teeth of the gears has a tendency to shred the oil, practically the same as if you would take a knife and draw it over a sheet of paper, you would eventually shred the paper. Consequently, we have a liquid grease which will overcome any tendency to shred. It will not break down as quickly as compounded oils, for the fact that compounded oils are not cooked the same as our liquid grease is cooked, therefore, the globules of our liquid grease are much stronger than the globules of compounded oil. We have had broad experiences with the lubrication of open herringbone gears and in some instances we have found that very heavy tarry materials have been used as a lubricant. No matter how careful the gears are machined and no matter how perfectly the gears mesh, when heavy, tarry, sticky supposed lubricants are used, the tendency is that the lubricant will pack at the root of the gear teeth and distort the mesh entirely. In many instances, some supposed lubricant must be heated before applying to gears. (I am now talking about open gears). When a lubricant has to be heated, it proves it contains asphaltum or some tarry compound. When a material of this kind is used, it is used as an economy feature, but it defeats the purpose entirely, for the simple fact that it gives no lubricating value to the gears in the first place, and the tarry nature means an increased consumption of power, and when you economize in the first cost of lubricants you are wasting in power. Our company has made a careful selection of material that is manufactured into gear greases. These materials are selected as carefully as the materials that are used in the manufacture of our best best master line of greases, which, we believe, to be the best in the world.

We would like very much to have some real information that we could give you regarding the time that the lubricant should remain in service of any gear cases. If you take your automobile transmission, it is generally supposed that you should change your lubricant about every 5,000 miles. A car making about 400 miles per week; then in 5,000 miles you should change the lubricant about every 13 weeks and feel that you are doing the right thing for your gears, because you have gotten the value out of your lubricant in that many miles. In reduction gear drive, if our lubricant is changed once in six months that is enough without any doubt or question, and you would have gotten out of your lubricant the value which has well paid for itself by, first, saving your equipment, and, second, in cutting down friction load, thereby saving power. These things have all got to be taken into consideration. The lubricants that are used in reduction gear drives or in open gears are just as important

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as any part of the equipment, whether it be the gears, the bearings or the housings; that makes no material difference. The question as to length of time a lubricant should remain in service. Each one of us has his own opinion. Put the proper amount of lubricant of the required quality in the gear case and don't disturb it for a given period, which, we will say, is six months. It probably would run 12 or 15 months, but in six months you have gotten the value out of the material, and you can well afford to take it out of the gear case and use it for some other purpose that is, perhaps, not so important as the lubrication of reduction drive gears. The lubrication of herringbone gears is certainly a strenuous part of our work, because herringbone gears chop up the lubricant very rapidly and uses up the lubricating properties of the lubricant so quickly more so than any other type of gears. In circulating systems we recommend our liquid grease; in the gear case not equipped with circulating system we recommend a semi-solid grease or a lubricant that will seek its own level in the gear case, and never fill the gear case too full. The changing of the lubricant at given periods is really worth consideration. If there are any of you who would care to take this matter up further with us, we would be glad to go into details with you. We have seen certain heavy, tarry lubricants used; with very poor results. One master mechanic told us that he used coal tar. I suppose it was not really coal tar, but we do find in some places still bottoms are being used which looks like coal tar. Still bottoms is the last thing found after everything is taken from the still, leaving still bottoms or residue. As you know, some oil refineries, they have got to find an outlet for every product and the consequences are that the still bottoms are mixed with oil and made into supposed gear greases. We do not operate an oil refinery, therefore, we are not compelled to find an outlet for still bottoms. A good many supposed gear greases are sold on first cost, which is in the other fellow's favor, but the difference in efficient service is in our favor.

Gustave Fast*: The author is, indeed, to be congratulated on his splendid work in presenting this paper, which covers such a wide scope in such a thorough manner and the following comments should not be construed as criticism of the author's work, but rather as an elaboration on the mechanical power transmission such as gearing, couplings, etc.

It is true as the author points out that the importance of accurate alignment increases greatly with the speed, but I cannot agree with him that a rigid coupling is entirely satisfactory for slow speed mill drive. With rigid couplings it is impossible to detect whether or not the connected machines have become misaligned since being put into service and it is seldom discovered until some trouble has developed either in the bearings or the shafts. Many a shaft has failed after years of service and the failure promptly attributed to poor material, whereas, in reality, it has been caused by severe misalignment of the two shafts being connected by a rigid coupling.

We all know how difficult it is to maintain alignment in three bearings, let alone four, and it is this constraint of a continuous rigid shaft in more than two bearings which is the cause of dangerous stresses resulting in failure of either the shafts or the bearings.

In connecting "Gear Drives," it is absolutely necessary to use a flexible coupling of proper type. Some ten years ago the writer connected numerous electric motor-herringbone gear drives by means of rigid couplings with a fair amount of success, although some aggravated cases gave serious trouble.

I then turned to flexible couplings as a remedy for the troubles developed, but got into even more trouble as the particular coupling I have reference to, having torsional resiliency, developed within itself serious end thrust which is absolutely fatal to herringbone gear drives.

Since that time, however, several good flexible couplings have been developed that have lateral flexibility to a degree that make them entirely suitable for gear drives.

The author seems to regard lateral pinion oscillation as some mysterious phenomenon. Were the author to use the words "Actually" in place of "Seemingly," and "Seemingly" in place of "Actually" in his paper on page 8, he would be more nearly correct.

The causes for lateral oscillations are generally well known among gearing engineers, but they may not always be frank to admit it. They are as follows:

1. Inaccuracy of tooth form and spacing of teeth, causing lateral oscillations within the gear members themselves.
2. End thrust from external sources. This can be almost entirely eliminated by the use of a lubricated flexible coupling, having liberal lateral flexibility.

The lateral oscillations of the pinion, due to inaccuracies in the gearing or other causes, as above outlined, may prove very serious in cases where flywheels are mounted on the pinion shaft on account of the large mass in motion.

It is well known that the impressed force is equal to the product of the mass and its acceleration. If we knew these two quantities with any degree of accuracy we could determine exactly the impressed force. The mass is easy to determine but the accelleration is very difficult to even approximate. Whether we know the magnitude of this force or not may not matter much, but if the oscillations are serious, we will soon find it out by the condition of the gear teeth after but short service.

This vulnerable condition can be almost entirely eliminated by mounting the flywheels in separate pedestal bearings and connect them to the pinion by means of lubricated, flexible couplings provided with ample lateral flexibility.

In a thus connected gear the impressed force would only amount to 5% of what it would be were the flywheels rigidly mounted on the pinion shaft.

The best position for a flywheel is, of course, direct on the slow speed shaft of the gear wheel, running at mill speed, but requires a very much larger flywheel, owing to the slow speed and is, therefore, an expensive proposition, but it certainly will protect the gearing against destructive shocks.

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The following are the main points to take care of in the design and production of good gearing, and the failure of any one of these conditions to come up to the required standard will be the cause of trouble.

1. Kinematically best tooth form to suit the individual case. This requires disregard of any commercial standard.
2. Correct material of gear blanks that have been properly heat-treated, so as to produce normalized and stable molecular condition of the metal.
3. Exact alignment of gear wheel and pinion in a heavy and very rigid gear case.
4. Extreme accuracy of gear tooth "Generation." This eliminates all types of rotary "Form cutters," as they cannot produce true involute tooth curves in helical gears.
5. Abundant lubrication of right kind and viscocity applied in the "right place." This, to a large degree, eliminates splash lubrication.

The requirements the author puts on a flexible coupling are ideal.

There is, however, one condition that cannot be fulfilled with any degree of safety, namely, torsional flexibility.

By providing torsional flexibility, in a coupling, we merely add a small mass to the flywheels of the system and we do this at the expense of a highly stressed spring member, which will ultimately break due to fatigue.

In my discussion on flexible couplings before this society in June, 1923, I pointed out that the function of a torsionally flexible coupling is to store up and give out energy in the manner of a flywheel, but whereas a flywheel will perform this function by virtue of its inertia the torsionally flexible coupling will do this by means of highly stressed springs.

In the first case, there is no fatigue, but in the second case, there is.

The fact that some of these so-called torsionally flexible couplings do not break their springs more often than they do is because they are so stiff that the spring members are not stressed high enough and consequently do not have any torsional flexibility.

In any coupling where the spring members are sufficiently elastic to provide torsional flexibility to a degree that is useful as an energy accumulation or cushion, they will soon fail, due to fatigue and hence such types of a coupling cannot be considered as reliable equipment worthy of being used on main roll drives in steel mill practice.

Lane Johnson*: Mr. Hurme has presented a wonderful paper on the subject of "Motors for Driving Rolling Mills." The data which Mr. Hurme has gotten together has long been needed. It looks very much as if the high speed motor and the gear drive have come to stay and we note that the manufacturers of electric motors are making every effort to produce highly efficient motors.

It is up to the manufacturers of gear drives to produce highly efficient gear drives which will be serviceable for connecting these highly efficient motors with the mills.

The manufacturers of gear drives are making every effort to produce gear drives which will run quietly and efficiently for long periods of time without attention. This means several things:

1st. The gears and pinions must be accurately cut and the material put into the gears and pinions must be of the finest which the steel manufacturers can produce.

2nd. The bearings and lubrication must be improved over what they are now to bring the new drives up to a point which will match the excellence of the modern motor.

Of all the conditions which govern the operation of gear drives, lubrication is by far the most important. Gear cutting today is pretty good; the material which goes into the gears and pinions is astonishingly good, but the lubrication will have to be greatly improved. This is the particular point which is receiving careful attention from the oil manufacturers and the gear drive builders.

C. J. Klein*: After having heard Mr. Hurme's paper, there seems to be little doubt left as to the advisability of using gear drives where it is possible to use a gear reduction ratio of about three to one. As the curves indicate, the original cost of installation is less expensive and the efficiency and power factors are better than on slow speed, direct-connected motors.

As the standard single reduction double helical gear unit has been discussed to considerable length by the previous speakers, it may not be amiss to bring to your attention a few special drive conditions where, without gear units, the installations would be far more expensive.

Combination spur and bevel gear drives have been used extensively on semi-continuous and cross-country mills, rolling billets, sheet bars, structural sections, rails, strips, etc.

The usual layout of the drives above mentioned is to have the motor connected to a spur reducing unit, the gear of which drives the line shaft with the bevel gear units connected to each mill through a leading spindle, pinion stand, and intermediate spindles.

While the consensus of opinion seems to favor individual motor drives for each roll stand, I believe the original cost would be very much greater and the upkeep about the same when using individual drives instead of bevel gears and one motor.

I might give an instance to prove this statement. On a hot strip mill, where five roll stands are driven by one 1,800 H.P. motor, the slabs are being rolled in, not more than three roll stands at one time. If these stands had individual motors about 2,500 H.P. of motors would be required. This increase in horsepower would also decrease the efficiency and power factor of the motors.

To conserve space and reduce cost, installations have been made where the leading spindle is omitted, the bevel gear being mounted directly on

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the mill pinions. Spur gears can also be mounted in this manner.

Combination spur reducing units and pinion stands are used extensively on cold strip mills on account of the small amount of space required. Reducing gears for this service have gear ratios as high as 22 to 1, while some ratios as high as 20 to 1 have been made with a single set of gears, it has been found to be less expensive to use two sets of gears for ratios above 15 to 1.

Drives for these mills are required to transmit from 50 to 450 horsepower at speeds ranging from 300 to 900 r.p.m., the usual motor range being a ratio of 2 to 1.

Another drive combination which saves both space and cost is the "Kennedy" double helical spur reducing pinion housing unit for driving "Lauth" three-high plate mills, the top and bottom rolls being driven through spindles and the small middle roll by friction.

John C. Reed*: Mr. Standing has raised the question of the safety of cast steel flywheels. Now to my mind, a cast steel flywheel is a good deal like bootleg liquor; it may look all right, but you cannot be sure how it is going to act the first time you try it.

Some years ago we installed a twenty-two ton eight-foot diameter flywheel in connection with a 1200-H.P. 6 pole, 25-cycle motor running at 500 r.p.m., giving a rim speed of 12,500 feet per minute. The general design was similar in many illustrations, which we have seen on the screen this afternoon, and we were told that this wheel had passed through the usual processes of manufacture. The first time we started the motor, the wheel flew to pieces before the motor was up to speed, causing considerable damage to other parts of the mill. We replaced the wheel with a plate wheel in which we had more confidence.

With this experience still fresh in my memory, I feel that these wheels should be tested out by the manufacturer before setting them up in the mill, where in case of a failure a portion may kill someone, not to mention the property damage which is sure to result.

H. S. Page†: From the data given by Mr. Hurme it is indicated that usually, when a flywheel is required in connection with a geared motor-driven mill, the more economical arrangement is with the flywheel running at the motor speed rather than at mill speed. Rough calculations on a wheel, designed for 50,000 H.P. seconds total stored energy for use in connection with a 72 r.p.m. mill, show that if the wheel is built for operation at mill speed it will be several times heavier than would be the case if designed to run at a motor speed of approximately 400 r.p.m.

This paper, which is based entirely on alternating current motor applications, shows that there is much less advantage in the use of gears on 25-cycle systems than obtain in connection with 60-cycle motors. In other words, if certain details of motor design were not fixed by the available line frequency, many of the difficulties incident to direct driven mills would be eliminated.

Present day applications necessitate the use of a large number of direct current motors, even in the larger sizes. On such machines the designer is at liberty to choose the most advantageous arrangement as to the number of poles for the motors, and the problem of selecting direct drives for this slow speed work is very much simplified by the elimination of difficulties incident to line frequency. Gears, therefore, lose much of their advantage in direct current motor application to steel mill drive as compared with alternating current equipment.

H. L. Barnholdt*: Mr. Hurme's paper has brought out very clearly the ever increasing tendency to use geared motors for the main roll drives, and undoubtedly the motor manufacturers have had a great deal to do with bringing this condition about. I should like to point out that in recommending geared drives more often than direct connected units, the motor manufacturers have not been actuated by any selfish motives. That this is true becomes apparents for two reasons. First, the cost of a slow speed direct connected unit is about twice as great, for motor alone, as the cost of a geared unit, so that to recommend direct connected units in every case would result in approximately twice the volume of business, for motor alone, as compared with geared units. Second, it might be taken for granted that the electrical manufacturers do not have a great deal of interest in selling these gears, which they do not themselves manufacture. The fact that at present geared motors are recommended and installed more often than slow-speed, direct-connected units, probably is because the electrical manufacturers in general realize that their own interests are best furthered by recommending that type of drive, which in a given case, will prove most economical.

R. L. Rapp†: I might attempt to speak about this frequency situation. Mr. Hurme spoke about the tendency toward 60 cycles and Mr. Shover, in his discussion, referred to the problem in detail and pointed out a particular case in which the cost of 25 cycle electrical equipment, if I remember correctly, was $8,000,000 as compared to $6,000,000 for corresponding 60 cycle apparatus. A case of this sort naturally demands that careful though be given to the purchase of 60 cycle equipment even though existing equipment be 25 cycle.

Another factor that is gaining increasing prominence is the question of buying central station power, which is almost always 60 cycle. As you know, some large mills are already purchasing power in appreciable amount. In order to tie in the central station power with the steel mill power system it will usually be necessary to use a frequency changer.

The electrical manufacturers a year or two ago were presented with a problem by a central station which was purchasing Niagara Falls power and converting this power by means of synchronous frequency changers from 25 to 60 cycles. Due to the different governing characteristics of the water wheel and steam turbine driven generator units, and, due to a certain extent also to line disturbances, much trouble was experienced in holding the frequency changers in step and securing desired load transfer. This problem was solved by making one unit of the frequency changer an induction machine and securing

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load adjustment by means of the well known Scherbius system. Four of these induction frequency changers are in service and giving satisfactory operation and a fifth is on order.

I mention this installation since problems involved in tying in a steel mill power system are somewhat similar. The induction machine provides a flexible coupling, as it were, between the two systems, permitting successful operation and providing a means for automatically maintaining the power transfer desired.

O. Needham*: It might be of interest to comment briefly on the subject of the type of secondary control to be selected for use with an induction motor when a fly wheel is to be used on a mill installation.

The paper today gives some very interesting curves comparing three different methods of secondary control for utilizing fly wheel effect on plate mills. The curves show that a liquid slip regulator is the best type of the three examples given. It should not necessarily, however, be inferred that the use of a liquid slip regulator represents the best practice for all fly wheel drives. Each of the three methods mentioned, namely, permanent slip resistance, notch back relay type, and Liquid Slip regulator has its field, and many installations require some study to determine the best combination of fly wheel effect and control scheme to use.

In general, it may be stated that on mills where the peak loads are high, compared to the average load and where an appreciable slowing down of the fly wheel is not objectionable, such as is the case with roughing mills and with fly wheel motor generator sets, a liquid slip regulator is the proper secondary control to select. On finishing and semi-finishing mills comparatively light fly wheels are used. These are used principally for taking care of unusual conditions such as an attempt to roll a billet when the temperature is too low, or where the peak occurs only occasionally as a result of overlapping, for two or three seconds, of several comparatively long passes. On these the use of a magnetic secondary with either a permanent slip resistance or a resistance and notch back relay may work out to be the preferred type.

Attention is called to this so that the idea will not be obtained that any one type of secondary control represents the best practice for every case.

W. O. Beyer†: Some questions raised here bearing upon practical operation and maintenance of herringbone gear drives still appear to await a complete answer.

The "V" and wedge action of double helical gears is not a positive means of maintaining alignment of pinion and gear in their plane of rotation. Consequently, a pressure endwise on the pinion shaft will throw the total tooth load momentarily upon one helix which in turn causes an oscillation of the pinion shaft in an endwise manner. If, on the pinion shaft fly wheels are mounted, this oscillation will become extremely violent and lead to excessive wear of gear teeth.

Therefore in coupling a pinion shaft to a motor shaft it is essential that the coupling used does not, because of overloading, wear or excessive misalignment, introduce end thrust between motor and pinion shaft. That is to say, the coupling must be extensible. The term "extensible" is used in a relative sense, meaning that the internal resistance of the coupling to telescoping action is less than the forces which might conceivably be applied in an endwise manner upon the pinion shaft and the motor shaft.

A typical case is that of a sheet mill drive on which after some years of service the coupling had become set and would not permit adjustment endwise of pinion and motor shafts while the drive was running. Here it was found that the weight of one man thrown against the exposed end of the motor shaft, using a stout pointed stick, could shift endwise the motor rotor and pinion shaft with flywheels, as far as back lash of the gears would permit, and thereby set up endwise oscillation of pinion shaft and motor shaft. With pressure of the stick removed this oscillation would die away in intensity and then at times increase again without interference, being least when the mill load was light and steady.

This coupling was rebuilt with the object of providing extensibility under light pressure and also a considerable degree of resilience. The function of extensibility is obvious. The function of resilience, however, is two fold. First, to permit the absorption of torsional oscillation in the driven system, which has a tendency to cause separation of gear teeth in mesh, and to make the pinion unstable as to its alignment with the gear in its plane of rotation. Secondly, its function is the reduction of impact stresses and contact pressures due to shock loads.

In the case of the sheet mill drive mentioned, it may be said that these measures brought immediate and complete relief, attributable mainly to the improvement in the coupling action. It should be said that pinion and gear, which were badly worn, were reversed to utilize new tooth surfaces so that at present there exists an unusually great amount of back lash in these gears. Nevertheless, their operation is equal to that of new gears. This is not an isolated case, but one of several, and the statements previously made do not conflict with this experience.

The question of direction of rotation occasionally creates discussion. It is true that if pinion and gear rotate so that looking down upon them pinion and gear teeth approach each other, the reaction of tooth load tends to lift the pinion shaft. If the tooth reaction is greater than total weight of pinion shaft and fly wheels the pinion shaft will bear against the upper bearing shells and pedestal caps. It should be noted, however, that the action on the gear shaft is downward on the bottom shells. It has been shown in practice that excessive peak loads need not produce pounding in the pinion bearings under these conditions. That is to say, pinion bearings can be fitted to take the load against the upper bearing shells and caps as well as against the bottom shell and do it without pounding.

It should be remembered, also, that in the case of the opposite rotation the gear shaft lifts under excessive loads and consequently will pound the same

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as would the pinion shaft if the bearings are not properly fitted.

W. P. Stark*: Does it make any difference in what direction the gear and pinion mesh, that is, if the apex should enter first, or if the outside of the rim should enter first?

E. Dukes: We make it a practice to have the open part of the helix to lead, as it forces the gear compound toward the center. If the apex of the helix leads the compound is forced into the bearings contaminating the lighter lubricant and in many cases causes heating of the bearings.

P. C. Day: It really makes very little difference. The idea that if you run in the opposite direction with the apex leading throws the grease into the bearings is hardly of much importance, because in a properly designed gear unit, very carefuly provision is made to prevent this from happening.

Another point about cast steel flywheels having some relation to bootleg whisky. I must say, having built flywheels of that type for fifteen years without an accident, I can scarcely subscribe to that idea. Cast steel flywheels should be made from selected material and very carefully annealed. They should be constructed so that shrinkage stresses and shrinkage cracks are non-existent, and a fair limit should be put on speed. Cast steel flywheels are used in Europe up to 20,000 feet per minute limit. Our ordinary speed is 15,000 feet. When speeds are unusual, plate wheels are, of course, necessary.

The practice of sending out flywheel sets without giving them a thorough test with flywheels mounted and run over speed is not followed by ourselves, or, I believe, by any reputable gear manufacturer. Every large flywheel we ship has been run in our own shop at considerably over the synchronous speed of the motor which will be used in the field. It is run in a position where it would do considerable damage to expensive machinery if it behaved like the one we heard about.

Pierre Dumartin†: Direct current is often used in Europe for rolling mill motors, especially when adjustable speed is required. To obtain direct current Ward-Leonard Sets are used in some installations, but more often synchronous converters and mercury rectifiers. The number of mercury rectifiers is quite large at the present time.

With direct current, direct-connected drives are used in most ratings above 500 horsepower, while below 500 horsepower gear drives are used and also some belt and rope drives.

With alternating current direct-connected drive is very seldom used for mills over 1,000 h.p., except when means are provided for power factor correction. It should be noted that the frequency of 50 cycles is standard in Europe and necessitates oftener than in the United States the abandoning of direct-connected drive.

Above 1,000 hp. gear drive is nearly the only one used.

Nevertheless, there are a few mills for structural iron, especially in Germany and in Central Europe, of 1500 and 2000 hp. which are still driven by belt or rope, but this is quite an exception. Between 500 and 1000 hp. geared main roll drives are the rule. About 80 per cent of all the existing installations are gear drives. In the new installations of that capacity gear drives are nearly exclusively used.

Up to 500 hp. gear drives are not so often used as this field is exploited by small steel mills who are numerous in Europe and in France especially. In these plants rope drive and perhaps more extensively belt drive are still preferred. The general arrangement of these mills is as follows:

The finishing stand is direct-connected to the 3-phase motor and roughing stand is driven by the same motor by means of a belt. In such installations the number of gear drives is not one-third of the total and the belt or rope drives each obtain about one-half of the remainder. In the new mills gear drives are more commonly used, but are far from being the standard. The small steel man is still hesitating about using gear drive because the first cost is higher and these are considered delicate in maintaining and not absolutely dependable. One tooth broken results in the breaking of more and obliged one to stop the rolling when with rope or belt, the plant is never out of order for a long time, which is a most important thing.

The floor space available for the installation of an electrically driven mill and also the local arrangement have some bearing on the selection of the drive.

If the floor space available is very limited, direct connected drive may be necessary on such account.

When the manufacture has a certain preference for a rope or belt drive, it is possible that this type of drive will be discarded because of the greater floor space required, and that finally a gear drive must be used. It is common practice to provide at least 8 times the diameter of the small pulley between axle length if any idler is provided. The use of idler is not to be recommended. If it were necessary to resort to an idler, it would be better not to provide any damping arrangement as this diminishes the main advantage of the idler.

Until 1910 belts were calculated from practical experience, the drives were always small and the speed of the belt was never higher than 30 meter seconds. Since that time research has been made and laboratory tests performed in order to meet the competition of the rope drive.

The vacuum treatment of the leather now makes possible the manufacture of belt having very small extension, high elasticity and high tensile strength, and owing to these improvements, it is possible to require more from the belt drive and to increase the speed considerably with increased guarantee. At this present time, belts made of several layers of leather pasted together, are used with speed up to 70 meter seconds.

For example a wire finishing mill including a 1000 hp. motor driven by means of a pulley 1.75 meter in diam. and a flywheel pulley of 3.5 meters on the finishing stand aside is in operation. The belt made of special leather (four layers, 740 millimeter wide and 16 mm. thick, was operated at 50.6 m/sec.

The reductions most commonly obtained with belt drive are between 2½ to 1 and 3 to 1. Few

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installations have reduction as high as 4 to 1 and 5 to 1. Use of the idler is very rare.

The actual efficiency of belt drive well designed and well maintained varies between 90 and 92 per cent. Some drive of great capacity have efficiency tested as high as 95 per cent and 98 per cent in exceptional conditions.

Up to 400 and 500 hp. and with speed of at least 500 rpm., the motor is provided with three pedestals, the pulley being located between the second and the third pedestal. In the case of higher capacity and lower speed, the pulley is separately mounted and connected to the motor by means of a flexible coupling.

Besides the above mentioned advantages there is one more reason for using belt drive, such a drive is more flexible and reduces the shock on the motor.

Rope drives are used to some extent in central Europe. They are less expensive than belt drives, and are much more dependable since the rupture of a rope does not stop operations for a long period of time.

It has the following faults, however: Sticking of the rope fastener in the grooves, unequal tension of the different cables and breaking of the slackening ropes. These faults lessen the efficiency, and we know of an installation with a 200 hp. motor, provided with a rope drive, which has been transformed to a belt drive and the consumption of power lessened by about 12 per cent.

Originally, round rope made of hemp was used exclusively. Now rope of octoganol trapezoidal and especially square cross-section are used, depending upon its application. The linear velocity may reach from 50 to 60 m/sec. for square cable of poor quality.

The efficiency is of the same order as that which is obtained with belts but somewhat lower.

A good example of this is a mill which is driven by a 2000 hp. motor, by means of 32 ropes 50 mm. in diameter. The velocity of the ropes is 45 m/sec.

The ropes used at the present time of good quality may be utilized with a tension of 4 kg. per cm.-2 in driving rolls.

Originally spur gears were used. The faults experienced during operations among the Europeans (rapid wear, fracture of the teeth, shocks, noise, poor efficiency, etc.) has developed this suspicion against the gears, which we have just mentioned on the part of the small metallurgist.

Since then much progress has been made, notably in the utilization of almost entirely the Herringbone gears.

The gear drive is in general separated both from the mill and the motor to which it is connected by a flexible coupling. In certain cases, the flywheel of the rolling mill is located on both sides of the pinion of the gear continuously permitting the gear to be strained by the shocks of the mill operations. This problem prevalent extensively in America is spreading in Europe. The pinion is nearly always made of forged steels or for low speeds cast in one piece with the shaft.

Very large pinions are made of forged or cast steel pressed into position and keyed upon the shaft.

The periperal velocity, allowed in our country scarcely ever exceeds 18 m/sec. with reference to the primitive circular path of the gears.

The parts of the gear, which have, perhaps, been most difficult to perfect are the bearings, especially the bearings of the shafts for high speeds, because it is quite difficult to determine the magnitude and the displacement of the resultant of the forces and reactions upon the bearings during the various phases of the progress of the operation (no-load, full load, over load). The coefficient of ordinary wear does not exceed 16 to 18 during continuous running and 25 for momentary over loads. These figures refer to ordinary bearings using lubrication with rings or under pressure, the bearing being lined with babbitt metal. The special bearing of the Osborne-Reynolds or Mitchell type are very rarely employed.

The gears are generally placed upon a solid base of cast iron, assuring rigidity of the arrangement of very great powers upon a solid foundation firmly grounded.

A protective gear case covers the gears. In certain types this casing is filled with oil in which the spur gears revolve.

The efficiency measured with the Herringbone gears, of very great power, reached 98 to 99 per cent in the first period of running, and for gears revolving in oil. After a few years of functioning, these efficiencies are lowered from 1 to 2 per cent because of wear.

The ratios ordinarily used lie between 5 to 1 and 6 to 1. Certain installations have 8 to 1 and over 9 to 1 of very small powers, beyond this we have recourse to the double reduction. The last arrangement is used to a very small extent in Europe. For gears of medium and large capacities a series of standard type has not yet been arrived at by European engineers. Consequently prices are rather high and delays rather long.

We might add that gear reduction, under the conditions referred to, is developing rapidly enough, and that existing installations, dating back a few years have given on the whole good results for Herringbone gears, especially of the Citro type. The objections to this type of drive are greatly disappearing in the large steel mills, but the small metallurgical firms still favor the belt and rope drives.

E. A. Hurme: Mr. Farrington asked how much end-play a wound rotor motor should have.

The end play on these motors should be sufficiently large to allow motor to run on its magnetic center without touching the bearings with the end collars on the shaft. In other words the bearings should not be exposed to continuous end thrust. To bring this condition about, allowing for manufacturing variations, the end play allowance is usually from 1/8" to 3/16" on each end, or double this for total.

I am glad Mr. Day discussed the flywheel effect. Personally, I believe the flywheel effects given are lower than desirable in a good many cases. We agreed to use these low values in order to be able to make better comparison between direct-connected drives and gear drives. It is well known that oftentimes it is almost impossible to obtain sufficient flywheel effect in a low speed drive, whereas, in the case of gear drive it usually is a simple matter to add a small amount of weight for increased flywheel effect.

Mr. J. D. Wright mentioned that this paper covers prices and performances for 60-cycle motors only.

Sixty cycle was selected for the sake of simplicity. To compare both 25 and 60 cycles would have made the paper that much longer. Mr. Wright is correct in that no reflection was intended in my remarks regarding the interruptions on that 4000 drive, due to insufficient flywheel effect.

I agree with Mr. Dukes that old, existing bevel gears are not very desirable where new motor drive is considered on account of high friction loads. As Mr. Klein said, new up-to-date gears have considerably less friction than the bevel gears built 15 or 20 years ago.

Mr. Hall mentioned that lubrication should be replenished every six months. Only a short time ago, one of the gear builders recommended to change lubricant once every five years, and if you miss one or two periods there is no harm done—some variation between six months and 5 years.

Unquestionably there is a practical limit to any desired flywheel effect, and as mentioned by Mr. Umansky, the power rate in the case of purchased power, the capacity of power plant, or to what extent it is desired to limit the power peaks is purely a local application and an individual problem. Mr. Day remarked that the flywheel effects given are rather low: Mr. Umansky believes they are higher than necessary. This only emphasizes the wide difference of opinion which exists regarding proper flywheel effect.

Mr. Fast mentioned that instead of using term "seemingly" it would have been better to use term "actually." As previously mentioned, I acted more as a statistician in conveying the opinions of different manufacturers, and I tried to inject into the paper as little of the personal equation as possible. I thought better to use the term "seemingly" than "actually" because it was the composite opinion of a good many individuals.

Importance of accurate alignment was discussed. In one instance known to the writer 1/32" difference in the position of a shaft caused greater trouble and in six months time wore the gear pinion much more than would have been caused by ten years' normal operation if the mill had been properly aligned.

I was pleased to hear Mr. Rapp mention about cost analysis, made by Mr. Barton Shover, which showed that, in the particular case referred to, there was a 20 per cent reduction in initial cost in favor of 60 cycle motors. In the case of smaller sized motors, 25 cycle machines are more expensive than 60 cycle motors of the same capacity and speed, but in the case of large motors, and especially of low speed the reverse may be true. The difference may not be as great proportionately, but above a certain capacity of low speed motors, the 25 cycle machine is cheaper than the 60 cycle.

Mr. Needham clearly brought out the fact that slip regulator is not a cure for all control problems for there are many cases where permanent resistance or a variable amount of resistance is preferable. There are many cases, especially on finishing mills, where slip regulators are not required.

I wish to take this opportunity to express my appreciation to the various electrical, mill, gear and coupling manufacturers, as well as, many operating men who so kindly assisted in collecting and compiling this data which we have presented today.

Inspection Trip—Brier Hill Sheet Mill of Youngstown Sheet & Tube Company

MECHANICAL INSTALLATIONS

By E. L. McELHINNEY*

DURING 1924 The Youngstown Sheet & Tube Co. built at their Brier Hill Works a complete new unit for the production of sheets. Equipment and arrangement will permit making either ordinary black sheets or full finished sheets. Initial installation permits widths up to 48" in any of the gauges and lengths produced on hand mills.

Sheet Bar Storage

As the sheet mill is only a hundred yards from the bar mill, the bar storage building is comparatively small, being but 75' by 325'. In this space there is a 325' unloading track, space for storing long bar, bar shear with scale and handling arrangement, space for loading pair furnace pushers and narrow gauge tracks leading into bar pickler. One fifteen ton two hook crane handles all material from incoming railroad cars to placing the cut bar beside pair furnace pushers.

Bars are cut on a No. 5 lever shear, this size having capacity up to 8" by 2½". Long bar is placed by the crane on skids beside shear approach table. Bars are hooked from skids to approach table and fed into shear by hand. The cut bars drop onto a rack from which they are taken by hand and piled on narrow gauge cars. When loaded, a car is pushed ahead across a scale and onto a temporary storage track, an empty being moved up beside the shear. This track, arranged as a runaround, permits the craneman to work at his own convenience without delaying the shearing.

From these narrow gauge cars, cut bar is taken by the crane to the pair furnace pushers.

Sheet bar can be pickled on a Mesta electro pneumatic machine, which is located in a 40' by 50' room adjacent to the bar storage building. A pickling rack is placed on a narrow gauge car and loaded in the bar storage building. It is pushed by hand under arm of pickling machine and after pickling, returned in same way to bar storage where bar is unloaded and carried by crane to pair furnaces. To allow ample time for loading and unloading racks, two tracks are provided, cars working alternately on both.

A Mesta electro pneumatic pickling machine is the same mechanically as an ordinary steam ma-

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chine, but instead of steam as a working medium, compressed air is used.

The idea which prompted the introduction of the air machine was, we believe, the fact that the force of the plunger on its downward stroke is theoretically equal to the force required to raise the plunger. So, if the energy in the downward stroke could all be conserved, no additional power would be required except to overcome friction.

Practically, the piston is forced up by air at about 120 lbs. The exhaust is connected to a receiver under about 80 lbs. pressure. A booster compressor takes air from the exhaust receiver and returns it again to the high pressure receiver at 120 lbs. pressure. The power economy depends, of course, on the comparative costs of steam and electric power. A recent test of one pickler at this plant showed, from indicator cards, that it should require 33 electric horse-power to compress isothermally, the air being used. This horse-power assumed a compressor efficiency of 60 per cent. Some additional power is supplied in air from the service compressor, to make up leakage.

The pickling of the steel, as a process, has been very satisfactory.

Sheet and Pair Furnaces

Sheet and pair furnaces are located in a leanto 20′ by 325′ parallel and adjacent to the bar storage building.

The pair furnace pushers extend into the bar yard to permit the bar yard crane setting cut bar within easy reach. The pushers are single acting cylinder with counterweighted return, using oil for fluid under 150 lbs. to 175 lbs. pressure. Two pumps of about three H.P. each, afford the pressure, the supply being regulated by a 10″x8′-6″ accumulator. Observations since mill was started show that with eight mills operating these two pumps run but 15 per cent of the time.

The pair furnaces, built under license to use the Costello patents, are charged, of course, from the rear and bars are drawn from the front or either of two side doors.

Sheet furnaces have double chambers separate from each other and with flue arrangement known as the "hot hearth" type.

For six of the eight mills the double chamber sheet furnace and the pair furnace were built together as a unit, while for the other two mills, the sheet furnaces are built independently with their two pair furnaces built together. However, to insure independent control, each double chamber sheet furnace and each pair furnace has an individual stack.

Both sheet and pair furnaces are fired with coke oven gas, but brick work and binding of sheet furnaces has been designed for easy change to the hand firing of coal. In case of a total shortage of coke oven gas, pair furnaces would be fired with oil or tar as no provision has been made for coal firing.

The gas burners used require a gas pressure of about 10 lbs. per square inch, which is maintained by two rotary blowers housed in a small brick building just outside the bar yard. Each blower is driven by a 60 horse-power motor.

Hot Mill

The Hot Mill building is 90′ by 450′ and is served by a 30 ton crane with 10 ton auxiliary.

The mill train consists of eight 29″ finishing mills and eight 29″ roughing mills, four of each and a drag being grouped on either side of drive. Two of the roughing mills are of balanced type, one with motor driven screw down and one with hand screw down. These two roughers are placed on either side of a pinion stand which drives the two top rolls. The other six roughers and all the finishing mills are of jump type. Nominally, the train is rated as one 56″ mill, three 48″ mills, two 44″ mills and two 38″ mills. However, various sizes of rolls and spindles have been provided to allow for almost any combination of sizes from 56″ to 38″. The mill train is very heavy; housings are 17 and 19 ton steel castings, mill shoes are extra large with a spread of 7′-0″, while spindles and couplings are large as possible. Spindle carriers have been provided for all spindles.

Drive

The drive is a standard type single reduction unit with two overhung flywheels on the pinion shaft. A 2,000 horse-power motor connected through a flexible coupling runs 235 R.P.M. at full load, while nominal mill speed is at 30 R.P.M., this being a reduction of about eight to one. The two flywheels weigh 47 tons.

Cooling System

Two fans of 30,000 C.F.M. capacity each, and a system of underground ducts, supply cooling air. One air outlet has been provided for each stand of rolls and for each sheet or pair furnace. The outlet nozzles will permit the man using the air to direct its flow in any direction and to regulate its quantity.

Break Down Pickling

Break downs are pickled on the same machine as sheet bar. The two tracks used for transferring bar to and from bar building extend on opposite side of pickler into hot mill building, where pickle racks are loaded and unloaded. Breakdowns may be weighed on a floor scale near pickle room.

Dipping

A dipping tank and drying rack has been provided for each hot mill. These are located on the mill standing, with the thought of making matching, dipping and furnace charging as convenient as possible.

Doublers

Doublers have been installed on four mills to allow the rolling of light gauge tight iron. These are of usual type and operated by air.

Squaring Shear

Five 156″ squaring shears are used for the eight mills. The shears are so located that the shearing operation transfers sheets from hot mill building to annealing building.

Scrap Baler

A scrap compressor of the heaviest type built is located in one corner of the hot mill building. The compressor proper with a working platform is set twelve feet above mill floor. This arrangement avoids the pits generally needed under a scrap com-

pressor, saves room in that pump, storage tanks, etc., can be set under loading floor and saves a bundle conveyor as the bales when pushed out of the machine, fall into a railroad car.

Annealing, Pickling, Finishing and Shipping Building

Parallel with and opening into hot mill building is an aisle 90′ by 950′ which, with its leantos, is used for annealing, pickling, finishing and shipping. The annealing end is served by a 40 ton crane with 10 ton auxiliary, the pickling and cold rolling departments by a 15 ton crane and the shipping end by a 10 ton crane.

Annealing

As mentioned under discussion of squaring shears, the squaring shear operator drops sheets in annealing building. After being opened and weighed, sheets can be annealed in either box annealers or a continuous normalizing furnace. There are eight double chamber single depth box annealers located in a leanto 26′ by 325′. Coke oven gas is used for fuel, although provision has been made for changing to hand firing coal without materially altering furnaces. One stack serves two chambers but dampers and arrangement of gas piping allow each chamber to be controlled individually. Doors are of the counterbalanced lift type. Boxes are charged and withdrawn by a charging machine, the box resting on brick piers while in the furnace. The nature of the ground made it cost practically nothing extra to provide space for recuperators under furnaces and in initial installation, recuperators were installed under one double chamber furnace. One type of tile is used under one chamber and a different type under the second chamber.

Normalizing is done in a continuous roller disc furnace 50′ long. Entry table, furnace rollers and cooling table are driven from one motor to insure a single speed throughout. A portable leveller can be set at delivery end of cooling table.

Sheet Pickling

Sheets are pickled on either of two Mesta electro pneumatic machines, which are housed in a leanto 40′ by 100′. As described under breakdown pickling, sheets are loaded and unloaded from pickling racks in main building and transferred to and from pickling machines on narrow gauge cars.

Pickled sheets are unloaded into a water storage tank which has two compartments and rests on a turn table. The tank is so located that sheets may be unloaded into one compartment, while at the same time an earlier load is being fed from the other side into a scrubbing machine.

The scrubbing machine is designed to flush sheets with hot water, brush both sides and wring the water from them. Upon leaving the scrubber, sheets pass through a drying chamber to remove any film of moisture.

Cold Rolling

Cold rolling is done on two trains of four stands each. Rolls are 26″ diameter by 50″ and 60″ long. Each train is driven by a 300 horse-power, 440 R.P.M. motor through a single reduction gear unit. Mill speed is 45 R.P.M.

The cold mill motors and drives are just outside wall of main building in a leanto which is used also as a substation and switchboard room. A second room of this leanto houses a service air compressor, booster compressor and spare, for operating pickle machines, together with high and low pressure receivers for picklers.

Finishing Mill

Finishing equipment includes two roller levellers, one patent leveller, two resquaring shears, one cutting up shear, one slitting shear and one oiling-machine. Finished sheets may be weighed on either a bundling bench scale or an ordinary platform scale and shipped on either of two tracks which enter the warehouse proper.

The warehouse is heated by a direct fired Lee Hot Air Heater.

General

Considerable study was given in design of mill to both light and ventilation. The monitors of buildings are very generous and fitted with top hung, mechanically operated sash. In the hot mill building motor driven operators will raise sash almost horizontal, thus giving an open monitor which can be closed in a few seconds. Fifty feet of monitor sash above main motor is of fixed type to guard against rain falling on motor. To provide light for squaring shear operators, a skylight was provided above shears.

Crane rails are 25′ above mill floor and lower chords of roof trusses are 35′. There are steel walk ways along all crane girders.

Such auxiliaries as roll storage, grease rendering, sanitary equipment, drinking water, etc., have all been provided. Also a pit for neutralizing pickle waste.

In making the general layout future extensions were kept in mind so that with a minimum of expense the present capacity can be doubled.

ELECTRICAL INSTALLATIONS

By E. F. RHODES*

Sixty-six thousand volt, 60 cycle power is furnished by the Pennsylvania-Ohio Power and Light Company to our Plate Mill Substation, and from there the service is extended over a 66,000 volt privately owned transmission line a mile long, to our Sheet Mills. A 5,000 K.V.A. outdoor bank of transformers steps this voltage down to 2,300 for the larger motors; while a 1,000 K.V.A. inside bank reduces the potential still lower for the smaller 230 volt units. These transformer capacities are large for our present requirements, but were installed to care for future extensions.

From the switching station adjacent to the main transformer bank, parallel 2,300 volt cable feeders lead to the switchboard station and the Hot Mill Motor House.

Two hundred and fifty volt D.C. power for cranes is generated at the Steel Plant Power House, and distributed through the Sheet Mill switchboard sta-

*Testing Engr., Electrical Dept., Youngstown Sheet & Tube Company, Youngstown, Ohio.

tion. In this station, are also housed the Low Voltage A. C. Distributing Panels, the Lighting Panels, Cold Roll Motors and Control, and Starters for the Air Compressors.

Each Cold Roll Train is driven by a 300 H.P., 2200 volt, 440 R.P.M., Wound Rotor Motor. Starting is accomplished by the closing of manually operated breakers in the station—motor operated secondary control cutting out rotor resistance—while from push button stations out in the mill the motor may be stopped.

Air for use on Picklers is made by compressors, driven by 167 H.P., 220 volt, 225 R.P.M., Synchronous Motors. Through an automatic starter, these motors can be started or stopped from push buttons at control panel or air compressor room. The make-up-air compressor is driven by a 100 H.P., 2200 volt, Induction Unit, controlled also by a push button starter.

A 2,000 H.P., 2,200 volt, 235 R.P.M., enclosed Slip Ring Induction Motor drives the Hot Mills. Switching and metering equipment and Liquid Regulator are installed in the Motor House. The Liquid Regulator inserts resistance in the rotor circuit at starting and during heavy loads. Manually operated forward and reverse switches are automatically locked out until regulator is in wide open position insuring maximum resistance at starting. Thermal relays on motor bearings protect them from dangerous overheating by tripping running switch. In addition, this motor can be shut down from two push button stations in the mill.

The motor being wholly enclosed is cooled by means of an air washer and blower. Air is taken from outside the building, in order to eliminate the oil vapors arising from the Hot Mills, which is difficult to eradicate. Interlocking of blower motor starter with main motor running switch, insures forced ventilation while mill is in operation.

The hot mill motor is supplied with space heaters designed to keep the temperature of the motor above that of the surrounding air, and thus prevents moisture absorption during shut down periods. This motor is run without an operator in constant attendance.

All cranes are of standard construction. The salient features are: All motors equipped with Roller Bearings; Protective Panels made up of Street Railway Breakers; Manual Control used throughout; Dynamic Brakeing and Limit Stops on all Hoists; Safety Switches on top Crane Landing, cutting out all motors; Safety Switches feeding Collector Rails mounted on columns and accessible from floor; Magnetic Sanders on Bridge Runway, operated from cage; access to crane landings by stairways.

All A.C. Motors, from 5 to 60 horse power, are equipped with roller bearings. Leveller Motors are equipped with manual control using resistance in primary circuit.

Lighting current is taken from a 3 phase, 2300/230 volt Transformer and so distributed that half or all of the lights in each section may be lighted as demanded. The general illumination intensity of the whole mill averages about 1½ foot candles.

Several electric heaters for the preheating of finishing rolls are installed in this plant. The device, consisting of two frames, are arranged to clamp to a pair of rolls in their housings or in a special rack built for this purpose. The uniformity of heating is excellent, and there is little distortion of the rolls. As heaters are applied to the standing rolls, no power is required to turn over the mill. By this method the rolls are practically in midweek condition at the beginning of the first turn.

The New Sheet Mills began operating about the middle of November, 1924. In January of this year, when the Mills were running full, 5,168 net tons were rolled. The Hot Mill consumed 131 K.W.Hrs. per ton. Cold Rolling, Annealing, Finishing, Lighting and other auxiliaries used 51 K.W.Hrs. per ton. The Load Factor for January was about 60 per cent.

Other electrical features might be enumerated that deserve mention, but these will be left to the comments of the visitors in the discussion which is to follow.

HEATING FURNACES

By STRICKLAND KNEASS, JR.*

IN the Hot Mill train of the Brier Hill Sheet Mill Plant of the Youngstown Sheet and Tube Company there are eight mills; each mill is equipped with one Costello Pair Furnace and one Double Chamber heating furnace. The Costello Pair furnace is designed so that the bars are charged in the back end and stacked vertically, being held in this position by a catch just inside the charging door. The gas burns above them and passes across the top and down under the bottom of the pairs and is discharged from the rear of the furnace. The Pairs are supported on skid bars. This not only gives very uniform heating throughout the bar, but maintains even temperature between each pair of bars pulled from the furnace. A hydraulic pusher, operated by oil, is used to move the pairs into the furnace.

The Sheet furnace is of the ordinary type, having a single arch spanning both furnaces. The gas is led from the furnace down underneath the beds in order to provide some heat in the bottom.

Several fuels are available for heating these furnaces. Coal is the ordinary sheet mill fuel, followed secondly by producer gas. It is felt, however, that having a supply of coke oven gas available that this would give a much cleaner fuel for the sheet mill. It does away with all the handling of coal, getting rid of the ashes and the smoke and dirt, which is a nuisance in most installations.

Coke oven gas is supplied from a battery of eighty-four coke ovens, having a yield of about 9,000,000 cu. ft. of 560 B.T.U. gas per day. This gas is distributed from the coke furnace to the open hearths, the plate mill, sheet mill and various other auxiliary uses.

As it was felt that there might be times when the coke ovens would not be operating and it would be necessary to operate the sheet mill, various sources of auxiliary fuel supply were considered and steps taken to insure the operation of the sheet mill at any time. The Sheet furnaces were equipped with combustion chambers so that grates could be in-

*Combustion Engr., Youngstown Sheet & Tube Company, Youngstown, Ohio.

stalled for hand-firing coal should the coke oven gas supply fail.

On the Pair furnaces it was decided that fuel oil would be a more satisfactory fuel and would eliminate the necessity of installing a rather bulky combustion chamber at the side. This combustion chamber would interfere seriously with the circulation of the ventilating draft between the furnaces and would make a considerably hotter mill than we would have if it could be omitted. Up to this time it has not been necessary to use these auxiliary fuels.

It was decided to use Surface Combustion Company's high pressure burners in order to supply the fuel to the furnaces. In this burner the gas is supplied at a pressure of 10#; the Roots positive type booster being used to pump the gas to this pressure. The gas is driven through a small orifice at the burner which draws with it the amount of air required for combustion. The air-gas ratio can be adjusted and practically any furnace atmosphere can be maintained constantly throughout the range of the burner.

It is, of course, necessary in Sheet Mill work to reduce the scale to a minimum and for this reason the burners are set so that there is small amount of unburned fuel constantly in the furnace. The gas and air mixture is driven into the furnace at a fair velocity, which tends to keep the gas in circulation throughout the furnace and maintain practically uniform temperatures in the front and rear.

The burners are controlled by a single valve which regulates the amount of gas.

There are sixteen (16) single chamber, single box annealing furnaces fired with coke oven gas. No burners are used in these furnaces as it is desired to get a delayed combustion, which will wrap the box and maintain uniform temperature, both at the bottom, sides and top. Box annealing furnaces have been so designed that recuperators may be used in case they are found desirable. Two of the furnaces are equipped with different kinds of recuperator tile. Sufficient data has not been accumulated at the present time to indicate whether the saving made by these recuperators justifies the expense of the installation. The furnaces are equipped, each with a Bristol pyrometer inserted through the arch of the roof; in addition to this pyrometers are placed in different parts of the box in order to determine whether the annealing time has been sufficient to equalize the temperature throughout the box and if the temperatures are correct for the products desired.

A 45 foot Costello Open Annealing furnace has also been installed for the special annealing of sheets. The furnace is of a normal roller bottom type and is equipped with 24 shafts; four alloy steel rollers installed on each shaft. The furnace is fired with coke oven gas supplied at 10# pressure.

The furnace is designed to give a maximum temperature of the sheets of approximately 1750 degs. and will handle about 5 tons of sheets per hour.

The Finishing Warehouse is equipped with a Lee Heating Furnace. This furnace is fired with coal, the gases passing over the top of a baffle the length of the furnace and then through a large number of steel tubes through which the air to be heated is passed. The furnace has a capacity of 60,000 cu. ft. of air per minute and will raise the temperature of the air 100 deg. F. The air is distributed throughout the warehouse through on underground flue and discharged through ducts into the warehouse along the walls at both sides. This maintains a circulation of the air in the warehouse as well as providing sufficient warmth to prevent the sheets from sweating.

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*Application of Synchronous Motors to Continuous Mills**

By F. O. SCHNURE†

DRIVES on continuous mills for rolling sheet bar and billets can be selected from the following:

1. Slow speed induction motor—directly connected to the mill.

2. High speed induction motor geared to the mill.

3. Slow speed super-synchronous motor directly connected to mill.

4. Slow speed synchronous motor directly connected to the mill.

Items 3 and 4 may also be considered as high speed units geared to the mill.

From the standpoint of reliability, simplicity, rugged construction, high starting torque and ease of control, the slow speed induction motor probably ranks highest as a dependable driver of mills. But in these days of the power factor clause in power contracts and increased plant electrification without substantial additions to the generating and transmitting equipment its power factor of from 70 to 80 per cent at from half to full load is a serious handicap.

The high speed motor with a gear reduction unit has come into general use lately and has the advantage of a power factor from 90 to 94 per cent at half to full load. The combination is also about 10 to 15 per cent lower in cost than the slow speed unit.

The super-synchronous motor has interesting
sibilities. It is a machine that starts with th
at standstill and the stator frame revolving
being brought up to speed by bringing t
rest by suitable brakes, thus automa
the load up to speed. The cont
practically none being required

*Presented at Philadelphia.

†Elec. Supt., Bethlehem Steel Co., Sparrows Point, Md.

chronous motor on the line. It may also be run idle as a synchronous condenser and perform a very useful service to the power system. Either idle or under load, the opportunity is there for power factor correction.

However this paper has to deal with the standard synchronous motor, having special features to give it the characteristics necessary for the drive on a six stand continuous mill estimated to require a 7000 HP motor.

Since the schedule for the proposed mill included the rolling of 15"x¼" skelp from 2" stock with provision for the future addition of two more stands to allow rolling from 3" stock it was felt that the peak power requirements at times might be very high, which would require an expensive gear set if a high speed motor was given consideration. There is no prejudice against reduction gear units as excellent service has been experienced on the fourteen sets in operation in this plant. But it was felt that in a drive of this size the fewer links the better and accordingly the slow speed unit received primary consideration.

The power factor resulting from the operation of 25 induction motors ranging from 500 to 5000 HP. on the intermittent loads experienced in rolling mill drives was such that the addition of any more reactive power to the system would seriously hamper operations.

Accordingly the builders of equipment of this size were requested to make a study of synchronous motor drives, and three of the questions encountered from them were: How much starting torque will be required? What is the friction load of the mill? What torque will be required for backing out cobbles? There was apparently no data available to answer the first question. Induction motors have always been used for driving continuous mills and since they have always been capable of producing a starting torque up to 2½ times the normal running torque, no one had found it necessary to develop the torque required to break away a continuous mill. The pull in torque required was fairly easy to determine from the friction load of the mill. The torque required to back out cobbles is variable, since the rolls are generally loosened when backing out cobbles and it is hard to conceive that it will require more than 10 per cent more torque than to break away the entire mill train. To determine the answer to the first question a tension dynamometer was used to measure the pull required to turn over the 3250 H.P. motor on the drive of a 6 stand Morgan Continuous mill now in operation. After various attempts, during which it was necessary to increase the capacity of our dynamometer by a lever arrangement, it was found that with a mill room temperature of 40 deg. F. it required 30,000 foot pounds to break the motor loose, 45,000 foot pounds to break the motor and beveled gears loose and 110,000 foot pounds to break the entire mill loose. The condition of the various couplings and spindles was such that the motor had to be turned 270 deg. before the entire mill was in motion. Once the mill is broken away, it is felt that the pull-in torque required would not be excessive since there is considerable drift after power is shut off showing that the friction load, which amounts to 188 K.W. at full speed, would not be serious enough to cause trouble. With this data at hand, the manufacturers were able to work up propositions. A 7,000 H.P. motor has a normal rating of about 370,000 foot pounds at one foot radius. The torque required to break the mill loose represents about 31 per cent of the available torque of the motor. This falls beyond the ordinary synchronous motors scope, but within the capacity of synchronous motors having some special features incorporated in the squirrel cage winding. One of the considerations of synchronous motor applications in this size is the k.v.a. that will be required during starting. It is not objectionable in this particular case to have the motor draw full load or even 150 per cent full load current during starting periods and designs can be produced that will give 40 to 50 per cent torque on from 50 to 60 per cent voltage taps with the above line current.

The capacity of 7,000 H.P. lends itself readily to the consideration of a synchronous motor for this drive, since 40 per cent of its normal torque gives a starting torque that compares to 80 per cent of the torque on the 3,500 H.P. motor that is applied to the usual continuous mill.

The prediction is made that the synchronous motor will be developed to be a worthy competitor of the induction motor on many mill drives. Power companies are going to demand higher power factor operation. More complete electrification of the Iron and Steel industry will require the greatest economy in the operation of power plants and transmission systems and the synchronous motor is one of the means to this end.

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*Worm Gearing For Electric Cranes**

By G. W. RICHARDSON†

I DID not expect that I would have anything for this meeting, as I did not have anything new to bring up, but at our March meeting it was stated that some of the large crane builders were building cranes with worm gearing instead of spur gearing, therefore, I thought as we have used hoists and cranes having worm gearing for many years in our bridge shop, that, perhaps, this would be a good subject for our experience meeting.

At Pencoyd, American Bridge Company plant, we have one 60 ton six drum 10 ton capacity each hoist that has been in use for over 30 years, and in this time we have only replaced five worm gears out of the six years in use, also we have two 30 ton three

*Presented at Philadelphia.

†Elec. Supt., American Bridge Co., Pencoyd, Pa.

drum 10 ton capacity each hoists, that has been in use over 30 years, with only replacement of three worm gears of the six gears in use up to this time, these cranes or hoists do not have any roller bearing for the thrust, we use only a threaded plug having a brass washer between the end of shaft and plug at each end of the worm shaft to act as a thrust bearing, on these cranes we do not have any oil boxes depending on the operator to keep the worms oiled and greased. These cranes have quadrant (4) thread 1" pitch, ratio 13¼ to 1, which gives a high efficiency so that we do not depend on the worm to act at any time as a load brake, we use a strap hand operated brake on the motor shaft, which is operated by the operator to stop and hold the load, then we use dynamic resistance for lowering the load so that the load can be lowered to about the same rate as hoisting, the maintenance on these hoists has been very satisfactory both as to gears and motor troubles. The 60 ton hoist, is operated by a 40 H.P. series wound old type Crocker-Wheeler motor, geared to the worm shaft through spur gear and pinion. The traveling motion has a 10 H.P., Crocker-Wheeler series wound bi-polar motor, these motors have been on this crane since installed.

The two 30 ton hoist has 25 H.P., Crocker-Wheeler motors on hoist, and 10 H.P. Crocker-Wheeler bi-polar motors on traveling motion since installed.

The ten 3 ton assembling hoist has not had any replaced worm gears since installed 26 years ago. they are two drum hoist 1½ ton capacity each, operated by 7½ H.P., type F, Crocker-Wheeler motors on hoist equipped with electric Q brakes on armatures of motors and used dynamic resistance for lowering and they operate very satisfactory, the worm on these hoist run in oil boxes having the plug and brass washer at each end of the shaft and a stuffing box ring around shaft at the inside end of oil box.

The eleven 2 ton one drum revolving jib cranes, we have in use in our machine shop for 22 years, we have had some trouble with these jib cranes, due mostly by overloading, we have bent the shafts and broken the oil box, etc., but they also have operated very satisfactory, especially as everyone who wishes to, operates these job cranes. All of these cranes are equipped with worm and gears of large pitch, so to have very little holding back power, they will not hold any load without the brake being on.

We also have two 30 ton loading yard cranes in use 18 years, the 30 ton hoist is equipped with spur gears, while the 10 ton aux. hoist has worm gears, we have not had any replacement of gears on this crane since installed, the aux. hoist operates more than 10 to 1 of the main hoist, all of these hoists have forged steel case hardened worms and phosphor bronze gears.

About a year ago we built one five ton two drum assembling hoist having the following data: manganese bronze worm gear 43 teeth, 1¼" pitch, 3¾" triple thread, 17 7/64" P. D., ratio 14¼ to 1. This hoist has not been in use sufficient time yet to tell anything about the maintenance, all of these hoists are slow speed cranes operating approximately 10 to 12 ft, a minute full load.

The trouble formerly encountered in using worm gearing for this class of work has been that the pitch of the worm and gears was built on the order of a chain block, that is, it took almost as much power to lower the load as it did to hoist the load, thereby, causing the worm and gear to wear rapidly and give trouble, but by using quadrant thread 1" pitch or triple thread 1¼" pitch gears have given excellent results, therefore, I do not see why worm and worm gearing on most general service cranes would not work very satisfactory, which would reduce the number of spur gearing and cut down repairs to gears, motors, etc., such cranes using worm gearing would reduce the vibration much less than spur gearing. The spur gearing causes considerable vibration, due to back lash after being in use for some time. This vibration is transmitted back to the armature and causes or helps to cause trouble with the armature and field coils grounding. On such cranes as pig iron cranes, operating in steel mill yards, loading and unloading pig iron and scrap by electric magnates, it may be possible that they would not give as good results as spur gearing cranes, due to the high speed of such cranes, both for hoisting and lowering.

Cranes equipped with worm gearing should have high, efficient quadrant or triple thread 1" to 1¼" pitch gearing, run in oil, made of forged steel, hardened worm and manganese or phosphor bronze gearing.

OBITUARY

Otto Schaumberg, aged 48, for fifteen years Sales Engineer of the Westinghouse Electric & Manufacturing Company, died Sunday, April 19th, 1925, following an illness of several months.

Otto Schaumberg was born in Germany. He received his preliminary education in the public schools of Dresden, Germany, and later was graduated from Mittweiea University of Dresden.

An electrical engineer respected by all the executives in the Steel Industry, Mr. Schaumberg contributed a great deal towards Steel Mill Electrification. He became a member of the Association of Iron and Steel Electrical Engineers in 1911, and engaged actively in all the Society's endeavors. His host of friends will be sorry to learn of his demise.

Peter D. Brown, formerly Electrcal Superintendent at the Ohio Works of the Carnegie Steel Company, died Saturday, May 9th, 1925.

Mr. Brown was one of the early pioneers in electrifying the Steel Industry. He became a member of the Association of Iron and Steel Electrical Engineers in 1907, and took an active interest in all of its affairs.